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United States
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Fire Management Notes

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Fire Management Notes

An international quarterly periodical devoted to forest fire management

United States
Department of
Agriculture
Forest Service

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Training Fire Sleuths of the Forest

Linda R. Donoghue and Arthur J. Sutton

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It has long been an axiom of mine that the little things are infinitely the most important.

—Sherlock Holmes

You know my methods. Apply them.

—Sherlock Holmes

When most of us think of wildfire, we don't immediately associate it with crime. But most human-caused wildfires are crimes, felonies or misdemeanors, and, like other crimes, require careful investigation to determine their cause and origin. Most of us probably don't envision ourselves as detectives like the wise Sherlock Holmes or the quick-witted Kojak. After a quick check of the fire scene, we're more apt to record our best estimate of the wildfire cause based on readily available evidence, if there is any, and move on to the next fire or return to more pressing duties demanding our attention. "Police work" is someone else's job. But that attitude is changing. More and more it's becoming our job, too.

Arson, for example, is no longer just a local or regional problem—it's a national one—and with the increase in arson crimes comes the demand for better fire cause investigation to determine who started the fires, why, and how. Better investigation enhances our ability to identify our human-caused wildfire problems and solve them.

One obvious way to improve investigative skills is through training. There are a number of wildfire cause investigation training courses around. We'd like to highlight one such course, hoping that it might in some way serve as a model for others interested in improving their investigative skills.

In June 1985, the Michigan Interagency Wildfire Prevention Group (MIWPG), a cooperative organization consisting of Federal, State, and private agencies responsible in varying capacities for wildfire prevention, sponsored a 5-day training course in wildfire cause investigation. The purpose of the course was to teach the participants the fundamentals and techniques of wildfire cause investigation and the prosecution process. The participants could then systematically determine the cause of wildfires and pursue their cases in court. They could also train their coworkers in the same techniques.

After hearing that the Minnesota Department of Natural Resources (DNR) has an outstanding team of instructors, the MIWPG invited them to teach a fire cause investigation course in Michigan. The five members of this team have extensive experience and training in law enforcement and arson investigation. They are also seasoned instructors capable of enthusiastically presenting interesting and relevant course material. To supplement the program, guest speakers were invited to discuss special topics. For example, a prosecuting attorney reviewed the legal process followed in civil, criminal, and juvenile cases. He discussed proper courtroom dress and demeanor and described the cooperation attorneys require of forest officers if they are to make good courtroom presentations. Another expert, a forensic specialist from the Michigan State Police crime lab, described procedures to use when collecting and handling evidence found at the scene of a crime.

To allow more one-to-one contact, the course was limited to 35 students who came from a number of different agencies—the Michigan DNR, Michigan State Police, USDA Forest Service, USDI Fish & Wildlife Service, and Michigan State Firemen's Association. Most of these students were either trained, professional law enforcement officers or forest managers responsible for fire cause investigation in their administrative units. Regardless of their background and experience, however, they were all attending the course to improve their skills and enhance their knowledge of wildfire cause investigation.

Whether it's the attention we pay to clues pointing to the origin of a fire or the procedures we follow to painstakingly document our observations, it is true that the little things are the most important (fig. 1). These activities and more are essential if we are to enhance our chances of successfully completing investigations and pursuing them in court. During

the training course, students learned the important details of good detective work. Classroom presentations, all recorded on videotape, included:

- A review of Michigan fire laws and principles of fire behavior.
- Clues to a fire's origin in burn patterns and fire direction indicators.
- Ignition devices used to start wildfires.
- Maintenance of case files and notebook records during an investigation.
- Procedures and techniques used when interviewing suspects and witnesses.
- The legal process used in civil and criminal cases.
- Profiles of habitual or purposeful fire setters.
- Photographs of evidence at the fire scene.
- Methods to determine if vehicle or structure arson started a wildfire.
- Collection and handling of evidence found at the fire scene.
- Procedures to safely stop and approach a vehicle to question the passengers.
- Surveillance planning, equipment, and techniques.
- Procedures to determine the cause and origin of wildfires.

Figure 1—*Can you find the matches that started this wildfire? Despite the fire's 5-acre size, a well-trained investigation team found these matches by carefully following clues to the fire's origin in burn patterns and fire direction indicators.*

Knowing that the "little things" are important in wildfire cause investigations, the students were given a chance to test their knowledge and hone their skills in a simulated wildfire situation.

Two field exercises, which were also videotaped, were conducted after the course work was completed. Before the first exercise, the Minnesota training team in conjunction with the Michigan DNR set six wildfires in a control area and extinguished them when they reached 1 to 5 acres in size. The students were divided into six teams. Each team was assigned a fire location and asked to find the fire's origin and determine its cause (fig. 2). After this exercise, each team described how it used burn patterns and fire direction indicators to locate the area of origin, which thus enabled the team to find the ignition device.

The second, more extensive exercise was designed to simulate the "real thing." Once again, six fires were set and extinguished and one

burn area assigned to each of the six teams. This time, however, members of each team had to go through the exercise just as they would in an actual wildland fire situation. Team members interviewed witnesses (role-played by volunteers) on or near the fire scene, prepared plaster casts of tire tracks and footprints, systematically searched the area for evidence, and photographed, collected, and preserved evidence. These activities were done in addition to all of the other activities essential to a good wildfire cause investigation. When the investigation was completed, a member from each team made a classroom presentation reporting what the team did and what it found during the course of the investigation.

One big factor contributing to the success of this exercise was the fire-cause investigation kit supplied to each team by the Michigan DNR. Housed in a specially designed, protective metal box, the kit contained more than 40 items necessary to conduct a thorough investigation of a wildfire.

After 5 days of intensive training, the course participants returned home equipped with the knowledge and skills to conduct wildfire cause investigations. Having this interagency cadre of trained investigators available, Michigan is one State well on its way to solving its wildfire problems.

Figure 2—*A fire investigation team carefully searches for the ignition device.*

It's up to us to learn the secrets that point to the cause and origin of wildfires if we are to make any headway in preventing them. Fire prevention planning is accomplished through information received from fire reports. The more accurate the information received, the better the prevention plan. Training in wildfire cause investigation is one way to improve this information and to become a Sherlock Holmes of the forest.

For further information about the course, the instructors, the investigation kits, or the videotapes, contact:

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BIFC in 1985...The Biggest and Busiest Year Ever

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The Boise Interagency Fire Center (BIFC), Boise, ID (fig. 1), turned 20 on April 1, 1985. However, no one took time to mark the occasion. Everyone was already too busy responding to a level of fire support requests unprecedented in BIFC's 20-year history. During one 10-day period in early July, the Fire Center moved more firefighters and other firefighting resources over a broader geographic area in a shorter time than ever before. By the end of the year, the Center had received reports of more than 83,000 wildfires and close to 3,000,000 acres burned across the United States.

Figure 1—*Boise Interagency Fire Center, Boise, ID.*

Weather's Impact

The stage was set for the 1985 fire season in December 1984. Much of the Eastern United States had well above normal temperatures, combined with precipitation shortfalls ranging from 25 percent in New England to 75–90 percent in southern Florida. The West suffered a dry and cold winter, with dry areas including southern California and sourthern Nevada, Utah, western Arizona, New Mexico, and Colorado. This trend of warm and dry weather in the East and cold and dry in the West continued through April. Most of the East and West Coast States were in severe to extreme drought by May. In June, extreme drought showed up in large areas of northern and southern California, northern Washington, central Idaho, and most of Montana. In Alaska, where the normal fire season peaks in May–July, conditions remained surprisingly wet and cool through late spring and early summer.

The Long, Hot Season

The 1985 fire season required record-setting interagency mobilization of personnel and equipment. The season really began in the Southeast in December 1984 with human-caused fires, aggravated by continuous drought, and continued with few breaks until late October 1985. Forest Service assistance to the States began in January when devastating fires prompted the Governor of Florida to declare a state of emergency. In April, fire activity in the Southeast declined for a while, but by mid-April there were major fires breaking out in Colorado and South Dakota, an unusually early time of the year for wildfire activity in those States.

In May, a new outbreak of major wildfire activity in the Southeast led to the commitment of six national fire overhead teams—the most ever to this area. These fires continued well into June, by which the extreme fire activity had spread into California, Oregon, and the Great Basin States of the West. During the height of the fire season, from mid-June through August, a record number of major fires burned in the West. In August, Alaska, which had been so cool and wet in the spring and early summer,

Figure 2—*BIFC mobilized 50,000 personnel during the unusually hectic 1985 fire season.*

suddenly broke into a large number of massive, lightning-caused wildfires in the interior. Nevada flared up again in mid-August, along with Oregon, Idaho, and Washington, in a series of major wildfires that continued though mid-September. Southern California, Oregon, and Washington rounded the season off with a flurry of severe fire activity well into October.

Major Forest Service fires included California's Wheeler and Gorda-Rat Fires, which consumed 118,000 and 56,000 acres respectively, as well as the Las Pilitas Fire, which burned 75,000 acres of the Los Padres National Forest. In Idaho, the French Creek and Savage Creek Fires and the Long Tom Complex burned a total of 55,240 acres of National Forest Lands. Interior and State Lands in Alaska had a combined total of 373,000 acres of fires. Oregon and Idaho also suffered severe damage from range fire activity—Oregon with 299,147 acres and Idaho with 243,275, almost all of which occurred on the Boise BLM District in southwest Idaho. The State most severely damaged by range fires was Nevada, where more than 750,000 acres burned, leading to serious concerns over watersheds and the possibility of the spread of Sahara-like desert lands.

The Fire Center's Response

For the Boise Interagency Fire Center, the 1985 fire season was the most active one in its history. During an average fire season, BIFC'S logistic support staff handles 2,500 orders for fire support resources—firefighters, support personnel, aircraft, and equipment. In 1985 the Center processed more then 6,500 resource orders. They mobilized 50,000 personnel, in comparison with the 10,000 mobilized during a normal fire season (fig. 2).

The Aircraft Desk normally orders 4 or 5 large contract transport aircraft, 50 airtankers, 60 light helicopters, and 1 or 2 military aircraft annually. During the long, hot fire season just past, they ordered an additional 65 light and medium helicopters to augment the contract ships and 155 charter flights to augment the 2,000 hours flown by the contract large air transports. The Forest Service Modular Airborne Firefighting System (MAFFS), a large, portable retardant pumping unit, was installed in the assigned Air National Guard and Air Force Reserve aircraft and activated to augment the airtanker system. The military was also contacted for 23 large transport aircraft to carry personnel and cargo. For the first time in 1985, the BLM contracted for a 727

jet large air transport. The 727 QC or "quick change" aircraft could quickly be converted from passengers to cargo and back again or fly a combination of the two. It flew 564 hours—282,000 miles, or the equivalent of 94 times across the continental United States. It carried 16,000 firefighters and 178,000 pounds of cargo at a considerable cost savings to the Federal Government.

In a normal year, the Forest Service Aviation Operations Staff inspects 40 airtankers, 5 large air transports, and 50 light helicopters to ensure they meet Forest Service operating and safety standards. This year they inspected an additional 35 light and medium helicopters along with numerous other aircraft to meet emergency mobilization needs. The Forest Service National Infrared Unit installed new, more sophisticated infrared detection equipment in its aircraft just in time for the 1985 season. The unit's two aircraft flew 545 hours worth of detection and mapping flights over 171 fires, often covering as many as three Forest Service regions during one evening's flight.

Innovations

There were many innovations by Fire Center Staff to meet mobilization needs. Not all were dramatic on the surface, but all had major impact on supporting the firefighting forces and protecting natural resources. In one example, the Forest Service modified all catering, shower, and transport contracts to provide for a net 5-day pay provision because of the extreme cash flow problems encountered by contractors trying to meet unprecedented demands for services. In one instance, a caterer invoiced the government for $627,000, with another invoice for $648,000 about to be submitted. The contracting unit obtained quick turnaround time on payment for catering services. Another caterer's payment check for $376,000 was lost in the mail, and a second invoice for another $319,000 had been submitted. Contracting arranged to wire him the second check, located the lost one, and had a check issued in record time. Normal time for reissuing lost checks is 2 months.

BLM's National Radio Support Cache got into the satellite communications business on the French Creek and Savage Creek Fires in Idaho with the help of the Army's Special Forces. They set up earth station-computer interfaces in fire camp and at the dispatch office in McCall, ID. Using this hookup, they were able to transmit both voice and high-speed data between remote fire locations and town. This led to far faster and more accurate ordering of fire resources and concomitant savings in suppression costs. Both the Forest Service and BLM radio caches supported a combined total of 133 fires with a total of 18,000 radios, antenna systems, and supporting equipment and personnel.

In the process of meeting record demands for resources, the Manpower Desk mobilized 192 twenty-person crews from the Eastern United States and 41 crews from Alaska. During 1985, nearly every one of the 50 States was either part of the problem or part of the solution. In the area of supplies, BIFC's Fire Warehouse moved 2.5 million pounds worth $12.6 million to fires (fig. 3). Incoming shipments were close to 3.9 million pounds and worth $9.5 million. Returns to the warehouse from firefighting agencies so far total $4.5 million. Meanwhile, the Equipment Maintenance Section was using its new Pulaski rehandling machine to rehandle 16,000 Pulaskis and shovels, which were then resharpened and otherwise refurbished and returned to the field for further use.

More than 9,300 firefighters were based at the Fire Center itself. They were housed at the National Guard Barracks at Gowen Field, fed (26,700 meals), and transported to and from the fires. The Transportation Section alone drove 242,000 miles with its buses and trucks over narrow and hazardous mountain roads, carrying firefighters and supplies to and from fire camps.

Summary

If all of this seems to be a litany of numbers, BIFC is in the logistics business. The Center acts as a broker of fire resources—finding where they're available and getting them to where they're needed in the most expedient and cost-effective fashion

Figure 3—*The BIFC fire warehouse moved 2.5 million pounds of supplies in 1985.*

possible. The participating players at BIFC are BLM, the Forest Service, the National Park Service, the Bureau of Indian Affairs, the Fish and Wildlife Service, and the National Weather Service. The Fire Center's area of service includes all of those agencies, the 50 States and, when requested, 7 Canadian Provinces as well. The 1985 situation required a massive interagency mobilization of resources at all levels. Before the season was over, BIFC had responded to requests for assistance in 18 States and 2 Canadian Provinces. At one point in early July, there were more than 17,000 firefighters on the line and major fire activity in 11 States: California, Oregon, Arizona, New Mexico, Colorado, Nevada, Idaho, Montana, Utah, Nebraska, and South Dakota.

The logistical efforts of BIFC were augmented by those of the States, counties and localities, the military, especially the National Guard, and the General Services Administration. A large number of able and dedicated personnel from Federal and State agencies came to Boise to work long hours in assisting BIFC to complete a task that would have been impossible to accomplish without their help. The fire season of 1985 will be the season against which mobilization efforts of the future will be measured for many years. ■

NFMAS Slide/Tape Available

The USDA Forest Service Cooperative Fire Protection staff, in cooperation with Colorado State University, has developed a new slide/tape presentation entitled "A Fire Management Analysis System for State Foresters." This slide/tape discusses the problems facing past and present wildland fire managers; provides an overview of the National Fire Management Analysis System (NFMAS) fire simulating model; and presents four case studies of the system's application.

The NFMAS model compares the economic efficiency of alternative fire management organizations and funding levels. It displays fire effects and their economic implications.

The slide/tape is not intended to train people to use the model, but rather to introduce the subject to fire planners and those associated with fire management, such as budget personnel and policy makers.

A copy of the tape may be obtained from the nearest USDA Forest Service region or area office with cooperative fire responsibilities or from the USDA Forest Service, Cooperative Fire Protection Staff, P.O. Box 2417, Washington, DC 20013. ■

A Video Image Analysis System for Measuring Fire Behavior[1]

Charles K. McMahon, Carl W. Adkins, and Steven L. Rodgers

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Procedures used to measure or estimate fire behavior often require investigators to assemble and integrate data from a panorama of highly variable fire processes. In order to establish quantitative relationships between fire behavior and fire effects, numerous measurements are needed. This process can be expensive, time consuming, and fraught with error when subjective observations and manual methods of analysis are used. Objective observations coupled with automatic analysis can overcome these limitations as well as provide new opportunities to better understand wildland fire processes.

In this paper, we describe a low-cost video image analysis system now being developed at the Southern Forest Fire Laboratory. An overview of the instrumentation and methods and a summary of a current application are presented. Although image analysis technology is widely used in other fields, we believe this is the first quantitative application in the field of wildland fire science.

Background

For both wildland manager and fire researcher, the required accuracy for estimating fire behavior varies. In fire control, one can visually recognize when a fire's intensity has reached serious proportions. Guidelines for fire control have been published that evaluate labor, equipment, and safety considerations for different levels of fireline intensity as determined by visual estimates of flame length (*2, 9*). Sometimes, subjective expressions such as cool, hot, low, medium, or high are used by investigators to describe a fire's intensity. Much the same subjectivity can be found in the expressions of prescribed fire practitioners. The terms "winter burn," "summer burn," "low intensity," or "high intensity" are often used in prescribed fire research publications to describe the fire treatment. Although qualitative expressions may be adequate in some instances, there are occasions where both high accuracy and precision are needed to properly evaluate fire effects and to establish quantitative relationships that can be used in fire models.

For example, relating fire behavior to fire effects requires measuring the variability of the fire's intensity and not just fire "averages." Two sites may be treated with fires yielding identical average values for fireline intensity. Yet, one site may have significant scorch and losses because a higher percentage of the site may have been subjected to damaging values of fire intensity.

Although some instrumental methods are available to directly measure fire behavior parameters, they are both expensive and labor intensive and thus rarely used. Consequently, most fire-intensity data have been derived indirectly from published relationships of intensity to fire spread, flame length, and crown scorch (*3, 4, 10*). Of these methods, visual estimate of flame length has been widely recommended in technical reports (*6, 7*). Unfortunately, the accuracy of the visual method is poor, and the procedures not well established. In addition, there is considerable confusion about the difference between flame height and flame length.

Rigorous continuous monitoring of fire behavior has been accomplished by scaling images from individual frames of motion picture film for flame characteristics (*1, 5*). Photo methods are useful, but they have limitations. Operational costs of photo methods (cost of film development, etc.) are high and followup analysis methods can be very labor intensive. Video methods, on the other hand, offer most of the advantages of photo methods without some of the disadvantages. Video methods offer real-time assessment of image quality, low operational costs, and high portability. Furthermore, video images are easy to retrieve and are readily adaptable to computerized analysis methods.

The availability of economical video equipment and low-cost microcomputer systems prompted our efforts to develop an integrated system for fire documentation and analysis.

[1]The authors wish to acknowledge the technical assistance provided by John Harbin, electronics technician, and Robert Burgess, physical science technician.

System Description

The system has two distinct subsystems: (1) The image acquisition subsystem that creates and records the image replica, and (2) the data analysis subsystem that digitizes, stores, and analyzes the data.

Image acquisition subsystem. This subsystem includes a video camera with integral timer, recorder, portable monitor (optional), and camera targets or reference points. Our initial work was accomplished with a consumer grade RCA VHS format video camera (RCA Model CCO15) and portable recorder (RCA Model VJP900). This separate camera and recorder unit was used for about one year but proved too bulky (total weight 6.7 kg) for some of the field applications.

At present, we are evaluating the performance of a more easily portable, integral camera/recorder unit (JVC Model GR–C1U). This unit, which weighs 1.9 kg, is capable of recording up to 20 minutes of video on a VHS–C cassette. The VHS–C cassettes can be adapted to standard VHS cassettes. Camera battery packs are either 30- or 45-minute capacity, depending on the model selected. Data can be viewed onsite on a real-time basis by use of the camera viewfinder or an optional portable color monitor. Figure 1 shows the separate RCA camera-recorder and the all-in-one JVC "cam-corder" system. An additional benefit provided by these systems is the opportunity to simultaneously record a time-correlated voice-log on the cassette audio track.

Image analysis subsystem. The analysis subsystem allows the user to examine images that have been stored on the VHS recording media and extract geometric information from the images. For fire behavior purposes, this information could be flame length, height, angle, or relative position. With the assistance of computer algorithms, other parameters may be described. By using information on a frame-to-frame basis, time-dependent parameters such as rate of spread can be computed. Most of these parameters are derived from x, y, z coordinate data from image features. The analysis subsystem is divided into three functions:

- Image playback.
- Digitization.
- System software.

Image playback. The recreated image used for computer analysis is produced by a high-quality VHS recorder/player. A primary requirement of this component is that it reproduce the playback video with as much precision in timing as possible to reduce image jitter during video and graphics mixing. Our initial work

Figure 1—*Video systems; separate camera and recorder on the left and combined camera/recorder unit on the right.*

was accomplished with a low-cost ($400) consumer grade recorder (RCA Model VJP900). This system was adequate for recording fire behavior but inadequate when used in the still-frame mode. We are now using a studio-quality editing recorder (JVC BR8600) that cost $2,600. This recorder has proved successful and facilitates higher speed image retrieval.

Digitization. Images may be digitized by means of a cursor or pointer whose vertical and horizontal movement is calibrated to register directly in real units. Video images can be viewed as a mosaic of small picture elements (pixels) that are arranged in rows and columns. To establish a point-to-point measurement, a cursor is positioned at one of these picture elements by means of a graphics pointer (mouse). The computer establishes and records the position based on x and y coordinates. The cursor is then moved to the next position and the steps repeated.

This information can be processed by the computer for measures of length, width, area, angle, and three-dimensional graphic reconstruction. In our system, digitizing is accomplished by electronically overlaying the graphics workspace of a desktop computer (AT&T PC6300) onto a playback image displayed on a color monitor. A graphics pointing device (mouse) is used for operator cursor control, allowing the operator to select features or contours on the image to be digitized. The image analysis subsystem components are shown in figure 2 integrated into a mobile work station.

Systems software. Control, calibration, and data saving functions are provided through a control program written in IBM (Microsoft) BASIC and 8086 assembler language. Digitized data may be written to a standard MS/DOS diskette providing data interchange capability with any IBM–PC compatible computer. By providing raw digitized data to a computer algorithm designed to specification, other useful information may be provided about the geometric character of the fire under investigation.

The following is a summary of system components and costs (development work is still being done on items 9 and 10):

Component	*Approximate cost*
1. Video camera/recorder	$1,500
2. Microcomputer	2,000
3. Graphics display controller	600
4. Graphics display	250
5. Graphics printer	800
6. Graphics pointer (mouse)	150
7. Portable color monitor (optional)	300
8. Workstation (optional)	600
9. Video mixer, sync. separator	—
10. System	—

Methods

Image acquisition methods. A 6-foot target was constructed to serve as a scaling reference for the imaging system. The target was designed for height adjustment and with an optional mount allowing for attachment to tree stems. By including a reference of known dimensions in the camera's field of view, objects that are the same distance from the camera as the reference can be compared, scaled, and measured.

Imaging accuracy was determined by performing a 23-point calibration against a horizontal scale at a working distance of 23 meters. After digitizing the 23 stations on the scale, the digitized values were regressed against the scale values to quantify the error. Results show a standard error of 2.0 cm and a peak error of 4.3 cm. The video system can also scale objects at distances other than the reference distance. This is accomplished by adaptation of a method previously reported that used photographic images *(1, 5)*.

The capability for adjusting scale for different distances from the camera has important practical value. For example, when monitoring line fires, specifically headfires, elliptically shaped fire fronts are formed and are presented on the monitor as a two-dimensional silhouette of the leading edge of the fire. Although the leading edge usually occurs near plot center, exact location is difficult to predict when placing the reference target.

Figure 2—*Image analysis subsystem components integrated into a mobile work station.*

Our system allows the operator to locate a baseline at the ground level position of the flames' leading edge, and with appropriate computer graphic aids, the image can be rescaled for distances other than the location of the target reference.

Our current system is limited to fires in somewhat level terrain. However, work is in progress to develop methods for slope scaling.

Image analysis methods. The present system is capable of providing measures of flame length, height, angle, cross-sectional areas, and forward rate of spread. Work continues on flame depth and midflame windspeed.

Because fire is a transient phenomenon, computer measurement of video images is accomplished by freezing individual frames from the 30 frames per second taken by industry standard video cameras. Reducing the still frame images of fire into digitized form is accomplished by the microcomputer. Computer algorithms have been incorporated into the digitizer control program so that the operator may compute the desired parameters interactively rather than having to run a postanalysis. The parameters may be saved into a data set so that large groups of data can be compiled permitting a quantitative examination of the fire variability. This information can be merged with prefire and postfire site characteristics taken from within the camera field of view. Subsequent rigorous interpretation of fire effects with appropriate statistical analysis is thereby feasible.

System Evaluation

As a practical test, the imaging system was used recently in both lab and field experiments in connection with the study "Flame Characteristics of Wind-Driven Fires in Surface Fuels" by Nelson and Adkins *(8)*. Twenty-two fires in a laboratory wind tunnel (fig. 3) and eight field fires (fig. 4) were studied to determine relationships between flame characteristics and fire behavior. In these experiments the system demonstrated the ability to provide clear, well-defined images of flames from which measures of flame geometry were taken. A distinct advantage was noted in the ability to rapidly review the fires a number of times in contrast with past attempts to use subjective observations for behavior measurements.

The internal elapsed time feature facilitated identification of points of interest along the fire's path. Rate of spread was plotted over time to establish spread uniformity from digitized

values of traverse distance and elapsed time. With this system, Nelson and Adkins were able to verify Byram's *(4)* flame length-fireline intensity relationship for several of the fires studied, but noted a distinctly separate mode of flaming for the laboratory fires where fuel consumption was approximately 0.5 kg/m^2. Flames of relatively constant length, height, and tilt angle are associated with this mode of burning. If similar behavior occurs in the field, this effect may be of significance in the burning of young stands or 1-year roughs in which fuels are light. Estimation of fire intensity from flame length by the Byram relationship could be misleading under these circumstances. Results also show that fire intensity can be determined in the field by expressing flame length in Byram's equation in terms of tilt angle and height. This method may be useful when flame length is hard to estimate visually or measure remotely with an imaging system.

System evaluation continues at this writing on a fire study in cooperation with the National Park Service at Everglades National Park in Florida. It is our hope that simplified procedures can be developed so that other investigators will consider adopting this concept when attempting to define fire variability and when developing quantitative fire effects relationships. We are not implying that this system is needed for all fire research investigations. Rather, we are suggesting that documentation of the "fire treatment" process needs improvement, and this system is a step in that direction. With some minor refinements in software and hardware, all components should be readily available at a reasonable cost. We invite your inquiry and observations concerning possible future applications.

Figure 3—*Southern Forest Fire Laboratory wind tunnel. Small-scale fires can be burned under controlled conditions of windspeed, fuel moisture, and fuel loading.*

Literature Cited

1. Adkins, C.W.; Clements, H.B. Photographic measurements of flame size over flat terrain. Funct. Photogr. 11(6): 32–34; 1976.
2. Albini, Frank A. Estimating wildfire behavior and effects. Gen. Tech. Rep. INT-30. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1976. 92 p.
3. Byram, George M. In: Davis, Kenneth P., ed. Forest Fire: Control and Use. New York: McGraw-Hill Book Company; 1959.
4. Byram, George M. In: Brown, Arthur A.; Davis, Kenneth P., eds. Forest Fire: Control and Use, Second Edition. New York: McGraw-Hill Book Company; 1973.
5. Clements, Hubert B.; Ward, Darold E.; Adkins, Carl W. Measuring fire behavior with photography. Photogramm. Eng. and Remote Sensing XLIX(2): 213–217; 1983.

Figure 4—*The image aquisition subsystem deployed in a field burning trial.*

6. Deeming, John E.; Burgan, Robert E.; Cohen, Jack D. The National Fire-Danger Rating System—1978. Gen. Tech. Rep. INT-39. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1977. 63 p.
7. Martin, Robert E.; Anderson, Hal E.; Boyer, William D.; and others. Effects of fire on fuels, A state-of-knowledge review. Gen. Tech. Rep. WO-13. Washington, DC: U.S. Department of Agriculture, Forest Service; 1979. 64 p.
8. Nelson, Ralph M., Jr.; Adkins, Carl W. Flame characteristics of wind-driven fires in surface fuels. In preparation; to be submitted to Can. J. For. Res.
9. Rothermel, Richard C.; Deeming, John E. Measuring and interpreting fire behavior for correlation with fire effects. Gen. Tech. Rep. INT-93. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 4 p.
10. Van Wagner, Charles E. Height of crown scorch in forest fires. Can. J. For. Res. 3: 373–378; 1972. ■

Economics of Fire Management

When a major forest fire is burning, the people trying to control it have a lot of factors to consider. They must use available personnel and equipment in a way that promises victory. But economics has a great deal to say about the quantities of people and equipment they can use. The amount of people and equipment used depends on the values that are being protected.

How much damage is a fire likely to cause? This is a question that fire management planners often have to answer, and researchers from the Pacific Southwest Station have been helping to find the right answer for individual sets of conditions. Wildfires sometimes destroy timber stands completely, but more often they cause partial loss and sometimes they even cause improvements. Some of the dead trees often can be salvaged; some of the live ones may have suffered only temporary setbacks. Other trees may not be damaged at all and many grow faster because competition has been reduced. How can all these situations be handled in a single analysis?

The researchers say that calculations of net value change provide the answers that are needed. The value of the stand after the fire can be subtracted from the value before the fire to estimate the net value change. A new procedure is being used in a fire management planning model under development at the Pacific Southwest Station. A sound basis for determining the appropriate values under protection should be one result of this work. ■

ICUF: A Procedure To Measure Prevention Successes

Earl Meyer and Duane Dupor

Forest fire specialists, Wisconsin Department of Natural Resources, Madison, WI

The success of a Forest Fire Prevention Program has always been difficult to measure. It is difficult to determine whether the reduction in fires is a direct result of your program or the weather. Wisconsin has developed a method that normalizes the weather

Using Ignition Components

Forest fire specialists Earl Meyer and Duane Dupor developed a technique of using cumulative ignition components in relationship to the numbers of fires from any cause. By using historical weather data and fire reports, a fire district can determine what the average numbers of fires are for a given number of ignition components.

For example, Wisconsin wanted to lower the incidence of forest fires caused by debris burning by 15 percent over a period of years. We had to establish a base period from which to work. We had each of the 10 forest fire control areas add up the total number of ignition components for a 5-year period (1979–83), then divide that number by the number of debris-caused forest fires that occurred during the same 5-year period. The answer is the number of ignition component units per fire (ICUF) or a number that relates fires to weather on a fire district.

All a fire manager has to do is begin keeping daily cumulative records of ignition components and debris-caused forest fires each fire season. This will give him a timely indication of whether the number of debris burning forest fires has increased or decreased in relation to past fire and weather history. Prevention plans can then be adjusted accordingly.

Wisconsin has used this system for two seasons, and the results are encouraging.

One big advantage of this system is that it can be applied to any size fire area where fire and weather history is maintained. This allows that area to make comparisons with itself and not with other areas that have different weather, hazard, and risk conditions.

Table 1—*Example of daily tally sheet used in Wisconsin ICUF program*

1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Date	**IC daily**	**IC cumulative**	**Areas ICUF**	**Normal fires × .85**	**Goal**	**Cumulative actual fires**	**Goal (+ or −)**	**Planned action**
3–1	20	20	50	.4	.34	1	+ .66	None
3–2	30	50	50	1	.85	1	+ .15	No
3–3	50	100	50	2	1.7	1	− .7	No
3–4	50	150	50	3	2.5	6	+3.5	Canvas Red Elm sub-div. one on one

Considerations

This program depends on two important considerations:

(1) Historical fire weather data must be available. Fire danger must be measured every day of the fire season so a cumulative total can be calculated.

(2) Accurate fire cause investigation is necessary.

We feel that by using ignition component units per fire (ICUF), the fire manager can judge the effectiveness of his fire prevention effort. Although it has worked well for Wisconsin in measuring debris burning fire occurrence, it may also be effective in measuring trends of other fire causes.

Example

Using a tally sheet similar to table 1 should help the areas target their debris burning problem and aid them in reducing the debris-caused forest fires by 15 percent. Using the base year average 1979–83, enter that number for ICUF in column 4. The following example shows how the tally sheet can help when the dispatcher begins to take down fire weather information in the spring.

March 1 is the first day that weather information is being taken at station x. The date is entered in column 1. The IC for the day is 20—enter 20 in column 2. Since this is the

first day, the cumulative IC is also 20—enter that in column 3. ICUF has been entered in column 4. Dividing ICUF into the column 3 number produces the number of normal debris fires for the IC. Enter that number in column 5. Multiply column 5 times .85 to establish your goal. Enter that number into column 6. Column 7 contains the actual number of cumulative debris fires to date. Column 8 indicates whether you are above (+) or below (−) your goal. Column 9 indicates what action if any will be taken to bring the debris fires to acceptable levels. A simulated 4-day tally is given in table 1 to aid you in getting started. ■

Michigan Agencies Promote Wildfire Prevention

Over 11,830 wildfires burned in Michigan during 1984, resulting in untold damage to natural resources and property of homeowners. For years, fire prevention priorities have taken a back seat to emphasis on suppression. The Forest Service, Michigan Department of Natural Resources, and fire departments have had wildfire prevention programs for many years, but the level of activity generally depends on the individuals involved.

To help increase the activity level, the fire agencies in Michigan got together to determine what they could do to promote wildfire prevention. An interagency wildfire prevention team was formed in 1978 by representatives of the USDA Forest Service, and USDI Fish and Wildlife Service, and the National Park Service; and the Michigan Department of Natural Resources. As the dialog continued everyone felt that the grass roots firefighters should be included in the group. So, representatives of the Michigan State Fire Chiefs Association, the Michigan State Firefighters Association, and the State Fire Marshal's Office were asked to join in the fire prevention effort. That brought all the major fire agencies together so that the prevention issues could be specifically addressed.

Committees have been established to work on individual issues facing the group, such as communications, data, and training. Today, the Interagency Wildfire Prevention Group is actively pursuing the goal of reducing the number of grass and brush fires throughout Michigan.

A program targeting fire-prone property was developed, an action plan is being used to funnel local wildfire danger information into one place for compilation and distribution to the news media, a Spring Wildfire Prevention Week was organized and held, and a Wildfire Cause Investigation course was given. Many fire prevention messages have been used by radio, television, and the newspapers. Wildfire prevention training materials are being gathered and cataloged for use by member agencies. This material is maintained at the DNR office in Lansing.

To help with the cost of wildfire prevention materials and activities, a special revolving account has been established. Member agencies may voluntarily contribute to the fund as their budget permits. The three national forests contribute on a percentage basis out of their prevention budget.

The Interagency Wildfire Prevention Group has made great progress in getting the main fire agencies involved in active fire prevention. Everyone has the same ultimate goal, but we tend to spin our wheels a lot. By pooling our ideas and resources and then pulling together, much can be done at the ground level to prevent wildfires. The ideas must be put into action; a fire prevented is a fire that will never need to be suppressed.

Arthur Sutton
Executive Secretary,
Interagency Wildfire Prevention Group, Forest Management Division, Michigan Department of Natural Resources,
Lansing, MI ■

Fireline Explosives—A Second Look

Dwight S. Stockstad, Troy W. Kurth, and Richard J. Barney

Respectively, research forester (retired), fire control section leader, and research team leader (retired), USDA Forest Service, Missoula, MT

Fire control agencies have periodically experimented with explosives for fireline construction, with particular emphasis occurring during the 1970's. The Missoula Equipment Development Center (MEDC) experimented with linear explosives (fig. 1) for use in fire suppression operations early in this period. This experimentation led to the development of a system that enables small, highly mobile crews to rapidly construct fireline.

A promising linear configuration explosive called Prima-cord was developed in cooperation with the Ensign-Bickford Company, Simsbury, CT *(1)*. Field tests at MEDC and extensive safety tests at the Naval Weapons Center, China Lake, CA, led to the approval of the Prima-cord fireline cord for fireline use by the Forest Service, U.S. Department of Agriculture. Prima-cord consists of an explosive core of PETN (pentaerythritol tetranitrate) encased in a fabric braid and a plastic jacket. DAP (diammonium phosphate) surrounds the explosive core, extinguishing the exploding fireball before it reaches the flashpoint of surrounding vegetation. Prima-cord is manufactured in a four-strand and a seven-strand configuration. Use of the four- or seven-strand cord depends upon the type of fuel present.

Another form of linear explosive is Water-Gel *(2)*. The explosive ingredient is ammonium nitrate, which is relatively inexpensive and much safer to handle than dynamite. A fuel sensitizer, thickeners, and a cross-linking agent are added to form a gel. The material is encased in a plastic tube resembling a sausage, about 1½ inches in diameter and 100 feet long. Although the casing is relatively tough, it is subject to tears and punctures if not handled carefully.

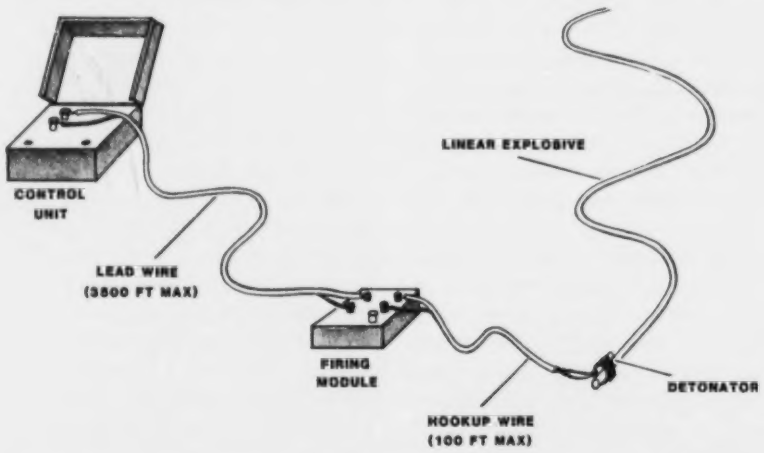

Figure 1—*Linear explosive charge attached to exploding bridgewire (EBW) firing system.*

Both Prima-cord and Water-Gel are detonated by an exploding bridgewire system (EBW) that offers maximum safety for blasting operations (fig. 2). Detonation requires a precisely timed electrical charge from a special firing set. The EBW cannot be set off by stray electrical currents, static electricity, or radio transmissions, as can standard electrical caps.

Missoula-based smokejumpers first used air-dropped fireline cord with good results on the Outlaw Fire in the Idaho Panhandle National Forest in 1974. Since that time, use by smokejumpers has been limited; however, when this technique has been used, results have been excellent. In preparation for the 1983 fire season, the Forest Service Northern Region increased its fireline explosive cord stock to 30,000 feet. In addition, a contract was enacted for additional fireline cord. Fireline explosive will be routinely used where 20 or more smokejumpers are dropped on initial attack.

Forest Service use of fireline explosive in other areas of the United States has been satisfactory, although limited. The Bureau of Land Management has had excellent results with fireline cord in Alaska. About 15,000 feet was used in wildfire suppression during the 1981 fire season. Some 74,000 feet of cord was stocked for use during the 1982 fire season. A

"Fireline Explosive Use Policy" section was included in the 1982 Alaskan Fire Suppression Field Reference Handbook.

The State of Washington Department of Natural Resources has been a leader in the use of fireline cord to fight wildfires. A standard issue of 5,000 feet of explosives is a part of the supplies sent to a project-sized fire on State lands. Approximately 81,000 feet of fireline cord was purchased in Washington from 1978 and successfully used on nine project fires. The State of Montana is also developing capabilities in this area.

Figures 3 and 4 show the excellent quality of constructed fireline obtained in two different fuels. The line width to mineral soil averages 12 inches. The soil cast to either side adds at least an additional 2 to 4 feet of effective line width. The dusting effect will reduce the intensity and spread rate. The more moist the ejected material, the more effective it is in slowing and halting the active flame front.

Water-Gel linear explosive (ammonium nitrate with an added sensitizer) is commonly used in constructing firelines for prescribed burns. An average of over 90,000 feet per year of Water-Gel explosives has been used in the Forest Service Northern Region for the past 3 years. This explosive has not been approved by the Forest Service for use on wildfires, pending tests by the Naval Weapons Center. Results achieved on prescribed fires with Water-Gel are comparable to those achieved with Prima-cord.

Despite good operational results, application of fireline explosive technology has been slow. A general survey by the Northern Forest Fire Laboratory of explosive use by suppression organizations in the Western United States revealed little use of the fireline cord during recent fire seasons. One reason seems to be the lack of firsthand experience and understanding of when, where, and how to use fireline explosives. The relatively small number of personnel trained as fireline blasters has, in some areas, discouraged use. The Northern Region qualified 70 fireline blasters for the 1983 season. Personnel trained in the use of explosives are most enthusiastic about its use. Blasters are being trained in increasing numbers, so this handicap should soon be eliminated.

The time required to deliver explosives to the fire is also an apparent deterrent. A lack of proper storage facilities in outlying areas contributes to the delay. Fire specialists commonly fear that explosives will not arrive in time for efficient use. Early anticipation of the need for fireline explosives

Figure 2—*EBW control unit (right) and firing module.*

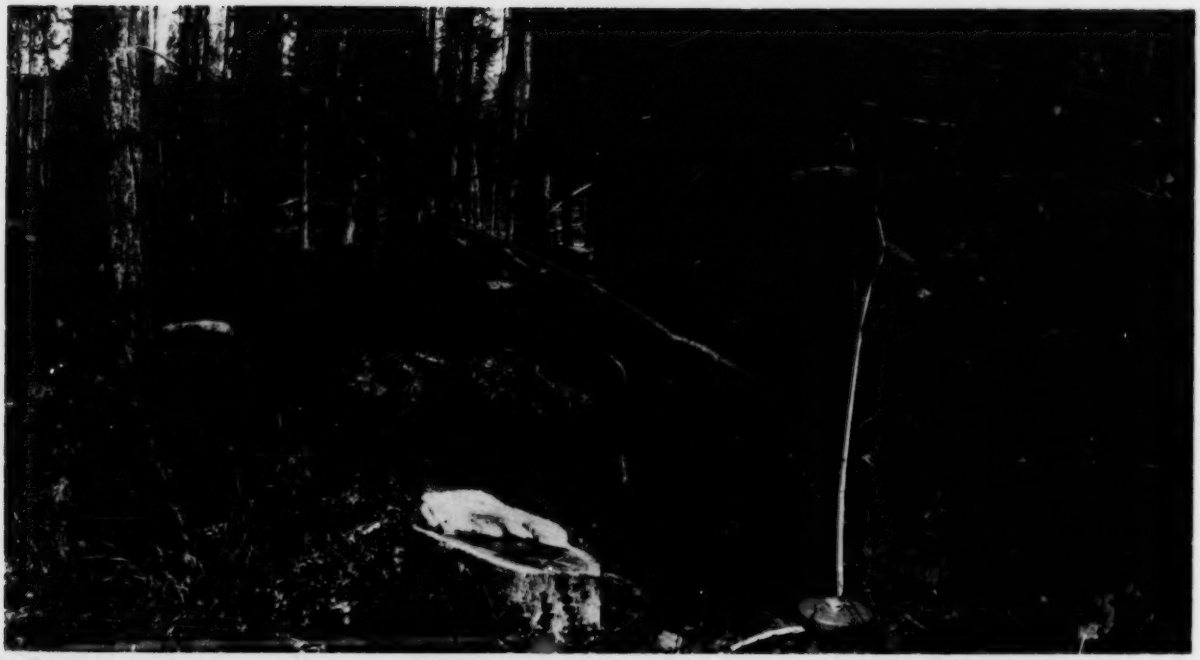

Figure 3—*Fireline blasted in moderately open ponderosa pine stand with light ground fuels, before detonation and after detonation.*

on a going fire would assure availability on the fireline at the most desirable time. A powder cache adjacent to the Missoula Aerial Fire Depot is being constructed to speed up delivery in the Northern Region. Current plans call for a 15-minute getaway time for parachute delivery of blasting crew and fireline explosives to a fire. Fireline explosives may also be air dropped to qualified fireline-blasting personnel already on the ground.

Lack of field application guides and related information on fireline explosives has also limited their use. Even trained blasters have usually had experience in only a limited number of fuel, cover, and terrain types, and may be hesitant to use explosives in unfamiliar situations. Many fire specialists have had little or no experience in the use of explosives. A guide to proper use of explosives under various conditions would help overcome this obstacle.

Fireline explosives may seem prohibitively costly for wildlife suppression, but the small number of personnel needed to blast a fireline and the speed at which it can be done more than offset the cost of the explosive. Approximate 1983 FOB costs for Ensign-Bickford fireline cord is $3.15 per foot. The Ireco Water-Gel costs about $0.55 per foot. The exact cost depends upon the amount purchased and the cost of delivery. The increasing costs of labor and the difficulty of securing trained workers are growing problems that outweigh the cost of explosives. However, depending upon crew size, fuels, and other factors, explosives can be very competitive in many cases and show distinct advantages in others. Most

fires in the Northern Region can be held and mopped up with a relatively small force once a fireline has been constructed.

Current research at the Northern Forest Fire Laboratory in Missoula has three objectives. First, establish the actual line dimensions accomplished by blasting in various fuel and ground conditions. Second, determine the rates and unit costs of blasted fireline. (The first two accomplishments will allow a valid analysis of blasting as compared to other line-building techniques.) The third objective is to develop field guides for operational use of fireline explosives.

Fireline explosives provide an excellent tool for suppressing wildfires. Use has been limited because of several factors, all of which can be eliminated through training programs, development of field guides, certification of fireline blasters, and resolution of transportation and storage problems. Removal of these limiting factors should establish routine use of fireline explosive technology.

Further information on supplies, training, and related information can be obtained by consulting the two references cited or by writing the USDA Forest Service, Equipment Development Center, Missoula, MT 59801. ■

Literature Cited

1. Lott, J.R. Fireline explosives—use and purchasing instructions. Special report, Missoula, MT: U.S. Dept. of Agriculture, Forest Service, Equipment Development Center; 1977. 16 p.

2. Ramberg, R.G. Water-Gel explosives for building fireline. In: Blasting prescribed fire control lines. ED&T 2697. Missoula, MT: U.S. Department of Agriculture, Forest Service, Equipment Development Center; 1978. 19 p.

Figure 4—*Fireline blasted in heavy* Ceanothus *brush, with numerous downed logs, before detonation and after detonation.*

GSA Reorganization

Ed Wirt

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No doubt many of you have heard one or more of the many rumors concerning the General Services Administration (GSA) support of the wildland fire program. It seems that if you don't like the rumor of the moment, just wait awhile and perhaps the next one will be more to your liking.

The GSA budget, like those of other Federal and State agencies, is being reduced. As a result, the Federal Supply Service (FSS) of GSA, which operates the National Wildfire Suppression Equipment program, is being reorganized. This reorganization will result in the closure or reduction of operations in some GSA regions.

The purpose of this reorganization is to enable GSA to continue support of the wildland fire community with a streamlined but more efficient organization.

The changes that will affect the wildfire management community are already taking place within FSS. First, overall management of the National Wildfire Suppression Equipment program is being transferred from FSS Region 8, Denver, CO, to FSS Region 7, Ft. Worth, TX. Second, FSS depots in FSS Regions 8 and 10, Auburn, WA, are being closed and the fire inventories located in these depots are being relocated in the FSS Region 9 depot at Stockton, CA, and to a lesser extent in the depot at Ft. Worth. Third, procurement of items for the wildfire program will take place within regional commodity centers with the responsibility to procure items on a national basis.

The FSS Commodity Centers will provide more efficient utilization of the resources available. Each will provide the full range of services such as procurement, inventory management, technical engineering, and requisition processing for all items managed by the center. The movement of FSS to regional commodity centers will reduce the number of procurement centers with national procurement support commitments from the present 16 to 8 by the end of 1986.

The Ft. Worth commodity center will manage all fire items on a nationwide basis and procure two-thirds of the items. The remaining fire items will be procured by the commodity center with national procurement responsibility for those items. The GSA Wildfire Suppression Equipment and Supplies Catalog will be continued by the Ft. Worth commodity center. Ft. Worth will provide the full range of services that pertain to the catalog ranging from addition and deletion of items to publication and distribution.

GSA will maintain adequate supplies of needed fire items, and there are no changes required in ordering procedures. We will be as ready to supply you for the 1986 fire season as we were for the 1985 fire season.

The position of National Wildfire Suppression Coordinator will be established in Ft. Worth, and will entail responsibilities in addition to those directly involving wildfire suppression. The coordinator will maintain coordination with the Boise Interagency Fire Center, Boise, ID, and closely monitor matters that have an impact on the wildfire community's supply needs.

Although this article may not have answered all your questions, it is hoped that it has been informative and that you consider it to be of value to your operations. Additional information will be furnished as it becomes available. ■

Underburning May Reduce Productivity in Ponderosa Pine Forests

It is widely believed that prescribed fires of low intensity beneath trees 25 feet tall or more increases their growth. Such burning, it is said, removes competing vegetation and increases supplies of water and nutrients for the trees. You can imagine the surprise of Pacific Northwest Station scientists, therefore, when they examined the growth after some fires under ponderosa pines in the interior West. Unexpectedly, they found that trees grew more slowly during the first 4 years after the fires than before. Height growth was down 18 percent and the increase in stem cross-sectional area (called basal area) was down 16 percent.

At this point, the scientists are unsure of the causes for the decrease in growth, so they are conducting additional studies. ■

Science Has Got Its Hands on Poison-Ivy, Poison-Oak, and Poison-Sumac[1]

Noel Vietmeyer

Professional associate, National Research Council, Washington, DC

In the summer of 1977 parched slopes of the Los Padres National Forest near Monterey, CA, were torched by lightning. For 3 weeks the Forest Service battled the flaming brush and trees.

But the Marble Cone Fire eventually spread to cover nearly 289 square miles of mountainsides, and the situation became desperate. "We were trying to fight one of the worst fires in memory and we couldn't keep a full crew on the fireline," recalls one forest engineer. "Guys were streaming out of the hills with their eyes running. It was California's second largest wildfire, with high risks of going completely out of control, and almost a third of our men had to leave the line with injuries caused by poison-oak!"

Poison-ivy is found in most of the United States (fig. 1–2), the relatively rare poison-sumac in the East, and poison-oak in the West (fig. 3–4). There is also a southeastern species of poison-oak locally known as Eastern poison-oak. Wherever they occur, these plants are the nightmare of gardeners, the scourge of hikers, and the curse of campers. At least 110 million Americans are clinically sensitive to the chemicals they contain; some 23 million are so sensitive that after even brief exposure they require a doctor's care. For millions of Americans these innocent-looking, rather attractive plants have made the outdoors a place of menace. To avoid contact, they have been forced to abandon their gardens, give up on picnics, and avoid the summer woods like the plague. Others venture out swathed in protective clothing, as if going off to battle, and on becoming casualties spend day after itchy day smearing their bodies with brown laundry soap or other home remedies. For all of these sufferers relief—at least in part as a result of the Marble Cone Fire—may be in sight.

Figure 1—*Poison-ivy in Florida.*

Unrelated to normal ivy or oak, the plants are members of the cashew family and are related to the cashew itself, the mango, and the lacquer tree of Asia. (Lacquer is a varnish made

[1]Reprinted from Smithsonian Magazine: Special thanks to the author for permitting this reprinting.

Figure 2—*Poison-ivy in Idaho.*

from this tree's poison-ivylike sap, which can also cause a rash.) Native to the United States, Asia, and Central America, these plants are almost unknown in other parts of the world. In the last century, for example, English visitors were amazed at the beautiful fall colors of poison-ivy and took some home. Because it was called "ivy," they planted it. Soon thereafter a British medical journal reported a new disease contracted only by women, who did the gardening, and concluded that it was a "hysterical rash"!

All parts of the country except Hawaii, Alaska, and some of Nevada contain poison-ivy, poison-oak, or poison-sumac. Poison-oak is actually one of the most widespread shrubs in California. Deer, cattle, goats, and other herbivores browse the nutritious foliage without apparent ill effects, but most humans touch the plants at their peril. And firefighters fear these vines and shrubs more than almost anything else. Breathing smoke from burning poison-ivy or poison-oak can have fearsome results: head-to-toe dermatitis, fever, horrendous lung infections, malaise, and even death when the throat swells shut. Moreover, firefighters cannot avoid the plants. At night, they cannot see them, and, besides, firelines must be cut whether or not any patch of vegetation is in the way.

More Trouble Than Cuts and Contusions

Jerry Oltman, a project leader for the Forest Service Equipment Development Center at Missoula, MT, was not at the 1977 Marble Cone Fire; he lives in Montana, 800 miles away. But his office designs and builds equipment for the Forest Service, and he decided that it should do something to avoid a repetition of the doleful experience. "Poison-ivy and poison-oak cause ten percent of all the Forest Service's lost-time injuries—almost twice as many as cuts, abrasions, and contusions combined," he says. "I figured that if we could find a way to reduce these injuries by even a small percentage, it would pay for itself many times over."

Initially he tried to encourage Federal agencies and pharmaceutical companies to lead a broad-based effort to develop a skin-patch test kit for sensitivity to the plants as the first step to reduce injuries. None showed any interest. To them, extensive poison-ivy research seemed neither a national priority nor a commercially enticing prospect. So Oltman, a forester who has never had a poison-ivy outbreak in his life, and who lives in

one of the few parts of the country that has none of the poison plants, took on the daunting task himself.

First he approached William Epstein, the Nation's most experienced poison-oak researcher. A dermatologist at the University of California Medical Center in San Francisco, Epstein is perhaps the only person in the country who speaks enthusiastically about these plants. His exuberance bursts out in lively staccato: "Poison-ivy and poison-oak are by far the major cause of allergic contact dermatitis in the United States; more people suffer from them than from all other allergic skin diseases combined.... No one counts the number of cases, but there are probably at least ten million a year nationwide. Poison-oak and poison-ivy are possibly the greatest cause of worker disability in the Nation; each year may bring more than 140,000 cases in the workplace, causing perhaps more than 152,000 lost workdays!"

Poison-ivy, poison-oak, and poison-sumac all contain a heavy oil called urushiol (pronounced *oo-ROO-she-ol*). It is clear, gummy, so incredibly reactive that a pinhead amount can cause rashes in 500 sensitive people, and so long-lasting that botanists have received serious dermatitis from plant samples stored away for more than a century. In one reported incident, lacquer from a Chinese jar, which had been buried for about a thousand years, caused dermatitis.

A Skin Test To Measure Sensitivity

With a contract from Oltman, Epstein and his colleague Vera Byers developed a test for determining a person's sensitivity to urushiol. "Most people actually don't know how reactive they are because the last time they had a dose was in childhood," notes Epstein. "But the sensitivity changes with time; as some people get older they get less reactive, particularly if they never encounter the plants. It works the other way, too. People used to wading unscathed through patches of the plants can suddenly break out."

The skin test is similar to the one used for detecting TB exposure. A small, standardized drop of dilute urushiol is placed on the arm. Seventy-two hours later, depending on the person's reactivity, there will be nothing, a red spot, a red spot with swelling and itching, or a red spot with blisters. It is simple enough for anyone to do, it comes with a little tube of cortisone gel to take away the rash, and the amount of urushiol is so small that the rash will not spread.

"For the first time we are getting baseline information on just how sensitive people really are," reports Epstein. "Between 15 and 25 percent of us are essentially immune, 25 percent are mildly sensitive and don't normally develop severe reactions, 25

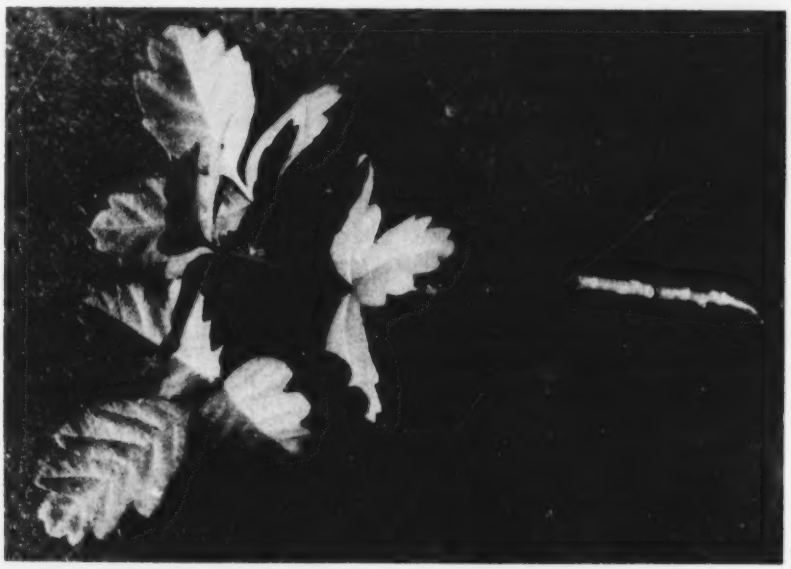

Figure 3—*Poison-oak in California.*

Figure 4—*Poison-oak leaflet.*

to 30 percent are moderately sensitive and break out significantly with the amount of urushiol found in one leaf, and 10 to 20 percent are so exquisitely sensitive that less than one leaf produces intense dermatitis."

Last year the Forest Service used the skin-patch kit to advise its firefighters on their susceptibility. Next year Oltman hopes to have it produced commercially. "One day you might see it in sporting goods stores," Epstein speculates. "People going fishing, hunting, or whitewater rafting could find out how sensitive they are before setting out, and companies could identify and provide special protection for workers most likely to suffer massive dermatitis in the woods."

The test kit doesn't help once an exposure has occurred, but advances in conquering the reaction are coming from immunologists. Urushiol, despite the plants' names, is not a poison; it causes an allergic reaction. As with other allergies, people are born without any sensitivity to urushiol. Babies, for instance, rarely get the dermatitis. Between the ages of 5 and 10, however, most children become sensitized, and from then on their immune system is reactivated whenever they again come in contact with the plants, even if it is 20 years or more later. It is not known how many exposures will cause the first response, but after the first response mere traces will again trigger the reaction.

Within minutes of contact, the oil urushiol penetrates the outer skin layers and begins chemically binding itself to skin cells. The body sees the combination of an urushiol molecule piggybacking on a skin cell as a foreign intruder. The immune system rushes large white cells called macrophages and T-lymphocytes to destroy the affected skin cells.

"It's the body's own overreaction that causes the complications," explains Epstein. "In sensitized persons the area fills up with the white blood cells and they release so much cell-destroying toxins that they tear apart even the skin itself. That's what produces the blisters and suppurating sores."

Research

However, the fact that urushiol generates an immune response gives researchers a chance to deliberately suppress the body's response. And this has now been accomplished experimentally.

Mahmoud ElSohly, a chemist at the University of Mississippi, has created a "masked" form of urushiol that binds less to the skin. Experiments with guinea pigs show that it can be

safely swallowed. When it is absorbed from the digestive tract, the liver strips away the chemical disguise, thereby releasing urushiol into the bloodstream. This release causes an entirely different kind of response from the immune system. Sensing the invader, the immune system may manufacture suppressor cells and chemicals; those that remain in the blood desensitize the person so that upon later contact with poison-ivy or poison-oak the body's response is muted.

"Urushiol is released where it is effective," explains ElSohly. "We can use fairly large doses, there appear to be few side effects, and the immunity is developed quickly." But the procedure is still experimental; clinical trials with humans at Epstein's laboratory in California as well as in Pennsylvania have not yet shown the effectiveness of this vaccine at safe doses.

Epstein and his colleague Vera Byers are developing their own poison-ivy vaccine in a related way. They use a modified form of urushiol that is unreactive on skin (and so doesn't have to be chemically masked), but that creates an immune response when small amounts are swallowed. "It desensitizes animals," noted Byers. "Now we're preparing to try it in humans."

Poison-ivy pills that immunize adults for a year and children for the rest of their lives might seem like the ultimate solution, but there is also hope for other forms of relief against the plants.

For instance, a scientific team at the Oregon Health Sciences University in Portland has developed a set of chemicals that shield the skin from urushiol. "We think people would appreciate something like a suntan cream that could be applied before going into the woods," says team member Susan Orchard. "Already we have found a preparation of organic salts that protects all test subjects from dermatitis for 8 to 12 hours when droplets of urushiol are taped onto their skin with a patch. It also protects about one-half of the volunteers for 48 hours."

With all this progress in research, some hoary folk beliefs are being debunked or confirmed as fact. For example, scientific evidence now indicates that it is impossible to contract dermatitis just by standing near the plants. Urushiol is a heavy oil that does not vaporize. Moreover, it is in canals inside leaves, stems, and roots; an undamaged plant has no urushiol on its surface.

The leaves are easily bruised, however, and insects chewing on them can produce spots of urushiol on the surface. Moreover, direct contact with the plant is not a prerequisite for getting the dermatitis. Shoes, clothing, tools, pets, or golf balls that have been through the rough can all transmit the sap to people. And they may cause rashes days, months, or possibly years after they touched the plants.

Today, the myriad of preventives and cures that have been proposed in the past can be better assessed. Home remedies, patent medicines, and "guaranteed" cures of the past have included bathing in horse urine or bleach; cleaning the skin with gasoline, morphine, gunpowder, buttermilk, marshmallows, or strychnine; drinking photographer's hypo; or rubbing on ammonia, mustard, Lysol, hair spray, clear nail polish, meat tenderizer, or toothpaste. All are probably useless, some even dangerous.

Drinking milk from goats that have grazed poison-ivy or poison-oak has long been claimed to give immunity. (Goats have such an appetite for all parts of the plants that, given time, they can eliminate them from a pasture.) "This is one folk remedy that probably works, although it never has been tested," says Vera Byers. "There's something magic about oral doses of urushiol oil, and goat's milk probably has traces of it. If you drink goat's milk you're probably doing about the same thing we are in our vaccine work."

Although we are now getting such practical insights into this affliction, Harold Baer of the Food and Drug Administration—himself a longtime poison-ivy researcher—cautions against too much optimism. "There have been innumerable remedies proposed in the past, and few have withstood the test of time." What is different today, however, is that researchers have designed experiments that provide fundamental and

reproducible information under controlled conditions. With these advantages, more reliable weapons are being forged.

"The poison-oak story is beginning to make more and more sense," says Jerry Oltman, who now looks back on the Marble Cone Fire with a different perspective. "Very little of it is science fiction anymore." ■

Additional Information

The USDA Forest Service has published several booklets on this subject:

- Poison-Oak and Poison-Ivy Dermatitis.
  Booklet no. 8167–2803 (August 1981)
- Preventing and Treating Poison-Oak and Poison-Ivy.
  Booklet no. 8167–2503 (August 1981)
- Developing Poison-Oak/Ivy Test Kit for Forestry Field Workers.
  Booklet no. 8367–2204 (October 1983)
- Testing Materials That Bond with Poison-Oak/Ivy/Sumac Urushiol.
  Booklet no. 8467–2203 (August 1984)

These booklets are available from:
USDA Forest Service
Missoula Equipment and Development Center
Missoula, MT 59801

Living More Safely in the Chaparral-Urban Interface

Fires sweep through communities, houses slide down hills, debris covers roads, and flash floods create havoc. These hazards of living in the brush-covered foothills and mountains of southern California often make the front pages of the Nation's newspapers.

In recent years, urban development has extended relentlessly into rural areas around many of the Nation's largest cities. Where the topography is relatively flat and open, this encroachment presents no great difficulty. However, where cities are surrounded by steep, brush-covered slopes, development has all too frequently resulted in loss of lives and property.

The brushland sequence of fire, floods, and erosion is particularly common in chaparral areas of southern California. Chaparral is a plant community in California that has adapted over millions of years to summer drought and frequent fire. Similar vegetation is found in regions of Mediterranean climate throughout the world. The plants grow dense and luxurious, and when this growth is followed by dry, windy winters, hazardous fire conditions are created. Urban encroachment accelerates the cycle and adds to the potential for tragic wildfires.

The Forest Service Pacific Southwest Station has published a guide, entitled "A homeowner's guide to fire and watershed management at the chaparral-urban interface," to promote living more safely in the chaparral-urban interface. This guide is available from the Los Angeles County Fire Department or from Information Services, Pacific Southwest Forest and Range Experiment Station, Berkeley, CA.

It describes preventive maintenance measures that should help reduce the damage from fire and flood. The information provided is addressed to homeowners, home buyers, developers, landscape architects, land use planners, wildlife managers, zoning agencies, city and county boards of supervisors, and other interested persons. ■

Crew Mobilization: Where Do You Start?

Stephen W. Creech

State fire coordinator, Indiana Department of Natural Resources, Division of Forestry, Martinsville, IN

So you want to be part of a fire crew on an out-of-State assignment? In 1985 there were 50,000 such people. When you are talking about mobilizing thousands of firefighters on short notice, everyone must be fully prepared. Are you really ready? Can you meet transportation deadlines? Are you fully qualified and fully equipped? Are your job responsibilities and personal commitments in order? Are you healthy? You may only have a few minutes to decide the answers to these and many other questions.

What follows is intended to help the crew boss/strike team leader, squad boss, veteran or rookie firefighter prepare for an out-of-State fire mobilization. The key to success, in this situation, is to have as many of the answers prior to the call as possible. In essence, the only task a crew leader should have, once the fire call is received, would be to fill the manifest with the names of those firefighters who can leave what they are doing for an extended period—a seemingly easy task, but the one requiring the most time.

Speed and safety are two key elements in any mobilization. One small bottleneck and an entire operation can come to a grinding halt. And because we are dealing with *wildfire*, the situation can become increasingly worse in a very short period of time.

Back at your home unit, whether that is a State, a park, a reservation, or a forest, lies the cornerstone of the entire mobilization concept. Lack of proper planning here can take away the effectiveness of rapid deployment. This is beginning to sound like a military operation. Well, isn't that basically what is happening? The only difference is the enemy is wildfire. There are certain things that can be done to assure a smooth, safe, and rapid mobilization.

First, let's look at what these home units can do. If the goal is to put together a qualified fire crew then a good place to start would be with those individuals who have met the requirements—in our case, personnel with red cards. Once the call has been received to pull a crew together, it is too late to start looking for possible inductees. To maintain an active roster it will be necessary to annually administer the physical test (step-test or alternate run), issue red cards, and update training. As personnel qualify and are placed on the roster, they should be provided with an information packet that explains the program and includes a needs checklist. Plastic cards are available that briefly describe a suggested gear pack. A crew roster should be maintained with the names, addresses, home and work phone numbers, and qualifications (red card or not) of all interested personnel. Copies of this roster should be in the hands of several individuals. At any given time one or more of the leaders may be out of contact. In addition, the list could be divided so that one person would have only 10–15 names to contact.

People do not like to go to work thinking that they will be home by 5 p.m. only to find out they are part of a fire crew that may not be home for 2 or 3 weeks. It won't always be feasible, but when possible keep personnel aware of the fire situation. Early communication can make a mobilization run much smoother and shorten transportation times immensely.

Because of safety requirements and the need for uniformity, crews can no longer wait until they get to the fire to get personal equipment. For that reason it is now essential that a fire cache be maintained, at a central location, that is equipped with all the required personal safety gear. This should include fire shelters with case, Nomex trousers and shirts, hardhats, hearing and eye protection, gloves, first-aid kits, and canteens. These items will provide you with the necessary safety equipment required in most areas. It is also very helpful if personal gear packs are available. The gear packs make baggage handling easier and help personnel stay within the 35-pound gear weight.

The call we have all been waiting for has finally come. Before we start down the active roster we need to make some key decisions. First, the decision must be made concerning who will serve as leaders. Crew bosses/strike team leaders and squad bosses must be selected from those that are qualified. These individuals are the first ones contacted. Next there should be a mixture of veterans

and rookies. A good rule of thumb would be to not have more than one-third of the crew as first-timers. Decide whether the crew will be pulled together at a central location or will they proceed directly to a transportation pickup point. Based on the mobilization time, will it be necessary to provide meals and lodging? Will it be necessary to arrange ground transportation? Now the list can be divided, and the calling begins.

If you are one of the lucky ones and have received a call to be part of the crew, you must now make some rather hurried decisions. You need to consider: your health, family and professional commitments, can you meet the mobilization deadlines, can you be gone for 2–3 weeks, who will take care of the dog—the list can go on and on. It is better to say "no" this time than to have to try to get home from a distant fire camp. Unforeseen emergencies are allowable, but prevention is still the best policy. If you have said "yes" you must now proceed to the preplanned mobilization point. Do so safely. You are not of any use to the crew if you do not arrive in peak condition.

We will now assume that the crew has assembled at a central location. A check must be made of the following items:

a. *Boots*. The footgear should be of the approved type and in good condition. Don't count on being able to obtain a new pair once on the fire.

Fire crew arriving at Boise Interagency Fire Center, ready for action.

b. *Allergies*. Identify the firefighters that are allergic to environmental factors or substances that might be encountered. Allergic reactions could be to stinging insects, poisonous plants (e.g., poison-ivy, oak, and sumac), pollen, foods, medicines, or other substances. These allergies should be recorded and any necessary medications carried.

c. *Medication*. Make a list of all prescription medication and be sure that it is in fact prescribed for that individual. If there is any question concerning the effects of medication as it pertains to personal performance, consult a pharmacist. If there is any question, have the individual wait until next time.

d. *Gearpacks*. Make sure that the packs are within the weight limitations. Gear weight should not exceed 35 pounds per individual. (Note: total crew weight should not exceed 4,800 pounds.) Briefly go over the suggested list of gear. There may still be time to find replacements. Now is the time to hand out the personal protective gear from the fire cache. Make sure all crew members have their complete allotment.

e. *Crewperson weight*. Weigh the individual, fully clothed, and then with the gear pack. It is a good idea to record these weights and tape them to the individual's hardhat. This can greatly facilitate air transportation, formation of helitack crews, etc.

f. *Forms*. Be sure that you have filled out all the necessary forms and that you have copies of required documents, such as cooperative agreements. *Each* crewperson should fill out an emergency contact information form. One copy of this form should remain at the home office and a copy should be retained by the crew boss/strike team leader.

If time permits, there are two more areas that should be covered. The first is to conduct refresher training on the use of fire shelters. A review of recent shelter deployment situations indicated the need for more hands-on training in the safe and proper deployment of the fire shelter. The last thing that you can do is to go through a briefing. The briefing should be factual, not speculation, and should be used to put everyone on common ground. Use this time to help put the rookies at ease. Try to think back to your first out-of-State assignment. A reminder of the "10 Standard Firefighting Orders" and "13 Situations That Shout Watch Out" is a good way to end.

Ground transportation has now arrived, and everyone is ready to embark on what may turn out to be the adventure of a lifetime. ■

Personal Gear Checklist for Crews on Fire Details

Needed

*Nomex shirt and Nomex trousers
*Fire shelter
*Hardhat with chinstrap and headlight clips
*Boots, heavy duty, lace in accordance with approved Guidelines for Boots for Firefighting
*Gloves, leather or equivalent, unlined
*Interagency Fire-Job Qualification Card
Duffel bag or large packsack
Socks; heavywork, wool (6 pr) light inner, cotton (6 pr)
Sweater or sweatshirt (substitute for light jacket)
Pants, cotton, work, cuffless (2 pr)
Shirts, cotton, work, long sleeved (2-4)
Underwear, 100% cotton (4 sets)
Handkerchiefs (4) (include bandana size)
Towel, wash cloth, soap
Toilet kit with safety razor
Toothbrush, toothpaste
Chapstick, foot powder
Watch
Cash ($25–50)

Optional

Pocket notebook, ballpoint pen
Small flashlight for camp use
Shoes or sneakers for camp use (avoid slippery soles)
Pocket compass
Pocket knife
Eyewash
Long underwear (for cold night sleeping)
Soap, laundry, small box

*Mandatory Fireline Items July 1985
The Crew Boss should carry a copy of the cooperative agreement with the Forest Service

Alaska Division of Forestry Goes TROLLing

Ron Hanks, John Warren, and Dennis Pendleton

Senior aviation officer, Alaska Division of Forestry, Anchorage, AK; electronics engineer, USDA Forest Service, Boise Interagency Fire Center, Boise, ID; fire management group leader, USDA Forest Service, R-10, Juneau, AK

Visualize a cool Alaskan summer morning: Salmon are migrating to spawning grounds, and fall rains have not yet muddied the crystal-clear runoff from winter snows. As you board the bright yellow and white aircraft, a tinge of woodsmoke accents the crisp air and you know it's a good day for trolling.

If your vision carried you off to a remote fishing spot you haven't heard of the TROLL system being used by the Alaska Division of Forestry (DOF). TROLL stands for Thermal Recorded Observation and Loran Locating and is a new system used for plotting fire perimeter maps and for reconnaissance of wildfires.

The concept was originally conceived in response to the need for increased surveillance of "limited action" fires, which are now quite commonly a part of the State's fire management scheme. Large parcels of land have been placed in "limited" or "modified" action categories for the purpose of making the most of the natural fire regime in the Alaskan bush. Remote lightning-prone areas can then experience a natural recycling of wildland habitat by fire.

After 2 years under the newly developed fire management format it was obvious that intelligence gathering on multiple fire occurrences was difficult at best. Reconnaissance was curtailed by dense smoke, long distances, and the lack of geographic references needed for accurate mapping. Something better was needed to reduce risk, and in the fall of 1984 a new project got underway.

Designing the System

The TROLL project was initiated with several considerations that ultimately determined the type of equipment to be used. Overriding the intention of making the system operational by the following spring were the realities of making staff available to work on a dedicated basis, a limited budget for equipment purchases, and lack of proximity of resources for the design and application of an aerial surveillance system.

With these complications in mind several management decisions were made to further define the scope of the project.

First, all equipment utilized would be commercially available. This would decrease delivery time, improve servicing of components, and reduce overhead costs. The next decision was in favor of forward looking infrared (FLIR) in lieu of more expensive line scanners or sophisticated IR cameras. FLIR was a compromise in some aspects but later proved to be quite capable of providing excellent results.

Finally, it was decided that the North American T-28B Trojan aircraft being operated by DOF was best suited for the reconnaissance mission. It was particularly practical because of long range, high cruise speed, maneuverability, and excellent visibility obtainable from the aircraft. Helicopters were not feasible because of logistical problems in monitoring a large protection area.

The North American T-28B selected for this reconnaissance project is only one of a small fleet of seven T-28's that are an integral part of the aircraft pool used by the Alaskan Division of Forestry. These ex-Navy aircraft were acquired by Region 10 State and Private Forestry through the Federal Excess Personal Property Program and put on loan to the State for deployment in their fire management system.

The T-28 had previously been outfitted with new avionics including 9600 channel FM radio capability to facilitate interagency operations, but more importantly Loran-C navigation was installed, which provided a means of acquiring latitude-longitude coordinates, as well as a multitude of other navigational data that would prove to be an asset to acquiring mapping information.

After the aerial platform and navigational difficulties had been resolved, the next obvious hurdle was to select appropriate infrared equipment that would lend itself to monitoring fireline activity. Assistance was received from the USDA Forest Service Advanced Electronics System Development Unit (AESD) in Boise, and by February 1985 the proper equipment had been acquired.

A Cooperative Effort

Both agencies by this time had agreed that benefit could be mutually realized by a cooperative effort.

In October 1984 John Warren, electronics engineer for the Forest Service AESD unit, had completed preliminary proposals for a system named Fire-Mouse-Trap, which was intended for operation from a helicopter. Modification of the F-M-T for application in the fixed-wing and Loran-C guidance resulted in the TROLL system currently under development by Ron Hanks, Alaska Division of Forestry Senior Aviation Officer.

Hanks, working with the USDA Forest Service State and Private Forestry Office in Anchorage, submitted a development project proposal that was approved by the Alaska State Forester and the Forest Service Washington, DC, Aviation and Fire Management Office. The proposal aimed at accomplishing the designated goal by fire season of 1985 and speeding up development of the F-M-T project by 5 years.

The State used funding acquired through annual cooperative fire assistance to purchase the FLIR unit and computer support equipment. It also contracted for computer software designed to integrate Loran-C with the on-board Hewlett-Packard (HP) portable computer for data storage and transfer.

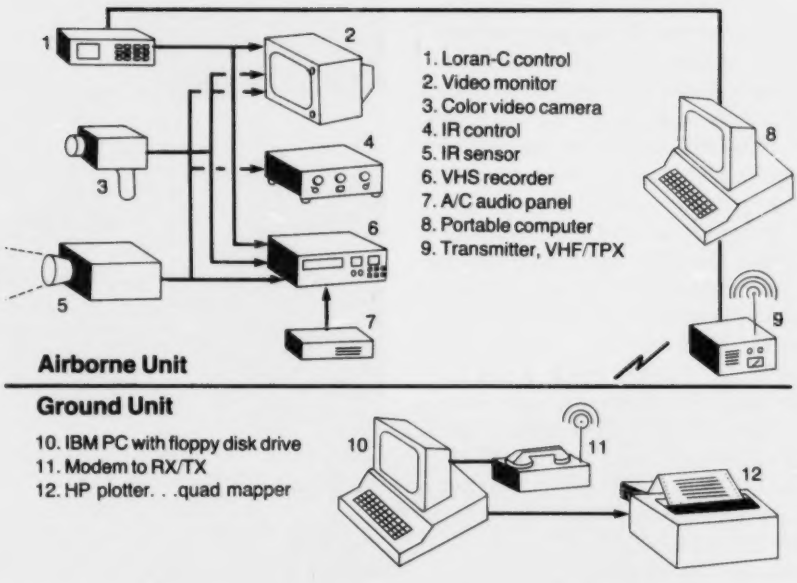

Figure 1—*Components of the ground and airborne units used in the TROLL system.*

Meanwhile the Forest Service was developing the software to drive the HP-computer and plotter units selected to perform the actual plotting. They also provided two HP-110 computers and a HP-7840 plotter for the State's use during the 1985 fire season.

By May 1985 the system was ready for experimental tests. John Warren and Dale Gable traveled to Anchorage to train the Alaska flight crew and to assist them with initial flight tests.

All airborne systems tested satisfactorily; TROLL was on its way toward operational deployment.

System Description

TROLL is a three-part system: airborne components, ground components, and air-to-ground transmission components, with the latter two being wholly dependent on input from the airborne system (fig. 1). Aerial components include a thermal sensing unit and color video camera that produce images on a common monitor and record the output on a standard ½-inch VHS videocassette recorder.

The airborne equipment was installed in the single-engine, low-wing, high-performance, two-person T-28 aircraft. The FLIR scanner head

sensor was mounted side by side with a color video camera beneath the aircraft in a specially designed compartment (fig. 2). The FLIR and video camera used a 45-degree (from vertical) viewing angle.

FLIR and color video cameras are used as aids to the pilot in determining the location of the fire perimeter. Color video and FLIR are also recorded and voice annotated for subsequent playback and review if necessary. The thermal IR view provided by the FLIR will often show the fire perimeter vividly when it cannot be detected visually or with color video.

The Loran-C is used to mark the aircraft's position in latitude and longitude. These loran position points are sent to the HP-110 for storage via the RS–232C interface. Accuracy of the system is dependent upon the loran system accuracy and the pilot's ability to stay over the fire perimeter in flight. The loran resolution (not accuracy) is in hundredths of a minute or 60 feet. Loran systematic errors can be calibrated out by flying over a known reference point and setting the loran or by simply using the reference to offset the plotter correlation on the ground.

The FLIR control unit, video monitor, Loran-C, video selector switches, power switches, and HP-110 personal portable computer are conveniently located for the back-seat operator (fig. 3). The pilot also has a Loran-C and a small video monitor. (Only one loran is necessary; it could be positioned for either pilot or operator use.)

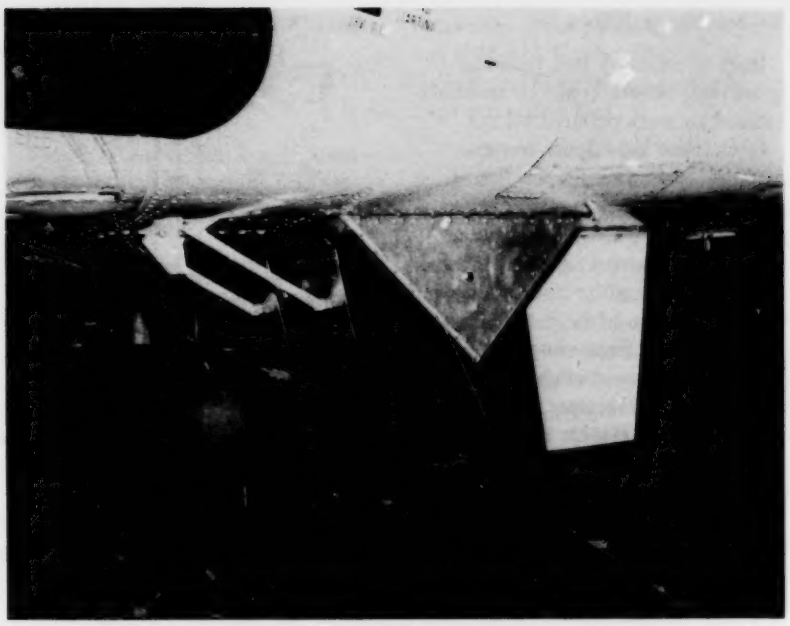

Figure 2—*Under-fuselage modification of T–28 aircraft to permit mounting of IR sensors.*

The FLIR used is an Inframetrics model 445, which has 21° × 28° field of view and considerably better resolution than the model 525 previously tested and in use by the Forest Service. The HP-110 is a briefcase-size personal computer containing its own rechargeable battery pack. It is the processor-controller unit and provides storage for the latitude-longitude points sent from the loran via an RS–232C interface arrangement.

The ground equipment consists of the same HP–110 computer and an HP–7580B drafting plotter. Note that all equipment is commercially available, not specially designed. New software is required for interfacing the HP–110 with both the loran and the plotter.

Additional interfaces with IBM-PC hardware as well as several portable HP plotters have been achieved, which greatly enhances the adaptability of the system.

Air-to-ground transmission can be accomplished through a Wulfsberg-Flexcom system. Latitude and longitude data points stored in the HP–110 can be transmitted via voice-grade radio to ground-link with a State IBM-PC located in each area field office. These data can then be printed out, used to plot a fire perimeter map,

or transmitted via land line to another terminal point for processing.

The map is "scaled" by the computer using only two correlation points. The file name to be used is entered, and the plotter plots the fire perimeter(s) and spot fires to scale on the map. If the fire is on more than one map, as fires are apt to be, the other maps can be entered and their portions of the perimeter will also be plotted. The entire ground operation can probably be completed by an experienced operator in 10 minutes or so, depending on the length of the fire perimeter, number of spot fires logged, and the number of maps needed to show the fire.

VHS videotape acquired by the flight crew is returned with the aircraft and played on a VCR to visualize color, IR imagery, and audio either from the cockpit intercom or FM nets. Tapes could be air-dropped if necessary.

Conclusion

The TROLL system was given the opportunity to prove itself in several different environments this season. It was used during Alaska's normal fire season in May, June, and early July. It was then deployed to the Lower 48 where it was used in mapping, detection, and reconnaissance missions in Nevada, Idaho, Montana, and along the Canadian border. As of September 1 the aircraft had flown 164 hours, mapped 22 fires, been credited with detection of 17 new fires, and flown over 70 hours of reconnaissance and mop-up verification.

As with any new system several "bugs" were encountered, and modifications to the software will be accomplished during the winter months.

Among changes already made are purchases of a disk drive and a smaller portable plotter. This equipment will increase the minicomputer capability and decrease shipping problems encountered with the larger HP plotter. The new plotter can be transported in the aircraft rather than requiring individual shipping.

Thermal sensing systems are relatively rare in the civil environment for a variety of reasons, including costs, complexity, and recent technological developments only now reaching the marketplace. Large military and governmental agencies have encouraged technological development for use in their specialized applications, but until recently these developments were cost prohibitive for single-agency ownership.

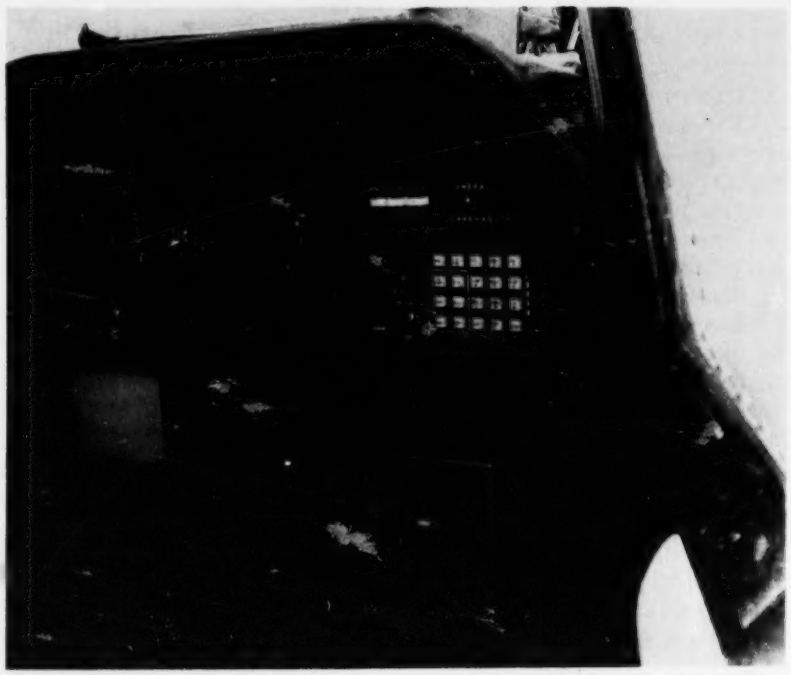

Figure 3—*Rear cockpit of T–28 aircraft showing loran navigation equipment, video infrared display, and IR image recorder.*

This project proposes and defines a new phase in the evolution of fire mapping. It has far-reaching impact on the methods and equipment that have been in use for over 20 years in the fire services. It also realizes significant cost savings while achieving the desired accuracy, timeliness, practicality, and availability for field operations.

Thermal recorded observation and loran locating may not be the most enjoyable way to TROLL, but many Alaskans have already benefitted from this effort. ■

Equipment investment needed for TROLL system, broken down by components

Unit	Type	Cost
FLIR	Inframetrics model 445	
	Liquid nitrogen or	$37,000
	Compressed gas	44,000
Video	VCR color camera, belly mount, solid state	1,300
	VCR color camera, hand held	600
	5" Video monitor, solid state	800
	3" Video monitor, solid state	400
	VHS video tape recorder	500
	Video switching panel	100
Computer/ Plotter	(one of the following)	
	Hewlett-Packard HP–110 portable computer	2,600
	HP–7580—plotter, 8 pen color	8,500
	HP–7550—plotter, portable 8 pen	3,100
	HP–7475A—plotter, portable 6 pen	1,600
Disk drive	HP Disk drive	700
Loran-C	ARNAV–AVA 40, extended range capability, RS–232 Interface	6,000
Complete package as operated by Alaska DOF not including installation:		$61,700
Recommended cost for helicopter installation:		$49,300

Predicting Fire Behavior by Computer

The person who wants to control a wildfire or plan a fire to improve forest or rangeland conditions must understand how the fire is likely to behave. The type and amount of fuels, the weather, the fuel moisture, and the topography determine a forest fire's intensity and rate of spread, but the relationships among these variables are complex. That is why Forest Service Intermountain Forest and Range Experiment Station scientists have developed a computer program named BEHAVE for predicting fire behavior. BEHAVE incorporates the results of years of research on fire behavior into an easy-to-use and versatile system.

BEHAVE is designed to be what programmers call user-friendly. That is, it prompts the user for information about fuels, weather, and the fire situation. This feature minimizes the learning time and greatly aids users unfamiliar with computer terminology in language familiar to them.

Such programs eliminate the need for the researchers to simplify complex relationships for the fire manager. The equations expressing these relationships are solved almost instantly by the computer, giving the fire manager the best available predictions.

Training in the use of BEHAVE has been provided to fire managers throughout the Forest Service and to their counterparts in the Bureau of Land Management, the Bureau of Indian Affairs, the National Park Service, and the Fish and Wildlife Service, as well as several State organizations and universities. One of BEHAVE's first major applications was during a rash of large fires in Montana in August 1984. Money saved in suppression costs on one 23,000-acre fire near Helena more than paid the development costs. ■

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Bates, Curt. Prescribed burning as a training exercise in NIIMS. 46(2):3-4.

Blank, Richard W.; Simard, Albert J.; Eenigenburg, James E. A tester for measuring the moisture content of dead fine fuels. 46(2):8-12.

Butts, David B. Fire policies and programs for the national park system. 46(3):11-17.

Chambers, John W. Using decision trees in escaped fire situation analysis. 46(2):13-15.

Cipalla, Rita. Where there's smoke, there's aerial firefighting. 46(1):3-5.

Cockrell, Patsy. 1985 forest fire prevention campaign. 46(2):16-17.

Daines, Gladys. Don't forget it. 46(3):20-21.

Davis, James B. The USDA wildfire program. 46(4).

Fly, Murry; Terry, Bill. Field exercises for ground cover fires: disaster management in action. 46(1):7-9.

Fulk, Thomas. Fire safety is a fulltime job. 46(1):10-11.

Gardner, Philip D.; Anderson, Earl B.; Huddleston, May E. Evaluating structural damage from wildland fires. 46(4): 15-18.

George, Charles W. An operational retardant effectiveness study. 46(2):18-23.

Graber, David M. Coevolution of National Park Service fire policy and the role of national parks. 46(4).

Halsey, Don; Whitson, Jim; Newell, Marv. Documentation of the incident command system. 46(3):18-19.

Hartigan, Arnold. Getting a handle on the pulaski rehandling problem. 46(1):6.

Hildreth, G.W. Aerial ignition device. 46(3):22-23.

Kraske, Robert. Incendiary wildfires. 46(1):16-18.

Mauck, Robert. BLM smokejumpers develop new parachute. 46(2):26-29.

McPherson, Guy. Prescribed burning of chained redberry juniper community with a helitorch. 46(4): 7.

Miller, H.N.; Newell, Marvin E. NIIMS and State forestry organizations. 46(1):25-26.

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Morgan, Clay; Matlack, Dale. History-making parachute jump. 46(1):19-24.

Paananen, Donna M.; Donoghue, Linda R. Fire prevention and the legal system. 46(2):24-25.

Pike, Roy; Minton, Mike; Beall, Ben. The California mini-kitchen. 46(1):12-15.

Riley, Douglas. DESCON. A proven method of reducing wildfire suppression costs. 46(4): 3.

Riley, Douglas. Fire load index. 46(4): 13-14.

Riley, Douglas J. The ground fire sprinkler: a new firefighting tool. 46(3):24-26.

Roberts, John E. Fire prevention—an honest effort. 46(2):5-7.

Roberts, John E. Protection of archaeological sites and special areas during prescribed burning. 46(3):9-10.

Rudnicky, James L. Estimating fuel moisture in the Northeast: fuel sticks vs the TI-59. 46(4): 4-6.

Stimson, Paul; Whitson, Jim. The ICS planning process. 46(3):7-8.

Taylor, Dale L; Gibbons, Regina Rochefort. Use of fire plows in a marsh. 46(3):3-6.

Whitson, Jim; Sety, Mike. GEOLOC-geographic locator system. 46(2):30-32. ■

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New Training and Publication Materials

The report on the fire entrapment incident on the Butte Fire, Salmon National Forest, indicates 60 lives were saved by fire shelters. Over 100 additional shelters were deployed during 1985. We further estimate two dozen additional lives have been saved by fire shelters since their use became mandatory on the fireline by some agencies in 1977.

Virtually everyone interviewed following entrapment situations believed hands-on shelter training is essential. Missoula Equipment Development Center's (MEDC) field trail publication "Your Fire Shelter" (August 1984) contains the most up-to-date information on fire shelter use and inspection. Key firefighting personnel should carefully review this publication. It includes such features as deploying your shelter, entrapment, inspection, and care and handling.

In addition, MEDC is in the process of updating the 16mm film on the use of the fire shelter, entitled "Your Way Out," to reflect important information gained through actual experiences. It should be available in the fall of 1986.

The life-saving success brought about by the use of shelters is unquestionable; however, steps need to be taken to ensure these successes do not develop into a complacency about fire safety or a reliance upon the fire shelter as something more than what it was intended for—a last resort. ■

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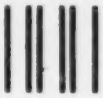

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Fire Management Notes

An international quarterly periodical devoted to forest fire management

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Cover: Fire shelter with section cut away to show fully equipped firefighter properly positioned. Fire shelters were heavily used during the 1985 fire season, especially on the Butte Fire. See articles beginning on p. 3 and p. 14.

Forest Fire Shelters Save Lives

Art Jukkala and Ted Putnam

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USDA Forest Service, Equipment Development Center,
Missoula, MT

The 1985 fire season proved especially active for firefighters nationwide. Drought and adverse weather combined to set the stage for extreme fire behavior. Massive crowning, spotting, and fast spread characterized last year's fires, which trapped more than 200 firefighters. But thanks to good crew leadership and the fire shelter, many deaths and serious injuries were prevented.

Fires trapped crews in the East early in the year. Out West, the most dangerous fires took place later in the summer. Two serious incidents occurred in Idaho fires. Some 82 firefighters deployed shelters while battling the Lake Mountain Fire on the Payette National Forest. On the Butte Fire, in the Salmon National Forest, a fast-moving crown fire chased four crews into safety zones. The firefighters set up shelters and survived despite intense heat and smoke. According to one crew boss, the fire shelter made the difference: "The shelter saved our lives. We had no escape alternative."

Reports from the Lake Mountain Fire tell us that most firefighters deployed their shelters under circumstances that were not life threatening. Nevertheless, the shelter is credited with saving a few lives, and it protected countless crew members from serious burns and smoke inhalation.

Lives Saved on Butte Fire

The Butte Fire entrapments clearly were life threatening. Eddie Abeyta, crew liaison officer, Santa Fe National Forest, who was one of those trapped, says, "We would've never made it without the shelter. There is no question about it. No shelter, no walk out of there."

According to Nick Montoya of the Carson Hotshots, who was trapped in the larger of the two safety zones, "Mortality might have been 75 percent without the shelter." Of the 73 deployments in both safety zones, investigators believe at least 60 firefighters would have died without the shelter's protection. Once again the fire shelter had proved itself.

We estimate that the fire shelter has saved more than 140 lives since its introduction in the early 1960's. The main reason the fire shelter saves lives is because it gives firefighters a way to protect face and airways. Breathing flames and hot gases is the greatest hazard in fire entrapment; thus protecting face and airways is vital. This fact cannot be stressed enough. A Federal Aviation Administration study of 1,140 burn cases involving 106 fatalities concluded that if the lower respiratory tree (trachea, main bronchi, and secondary bronchi) is burned, death is almost inevitable.

We also believe the more you know about the fire shelter, the more confidence you'll have in it, and the better prepared you'll be to stay put in your shelter should you ever become trapped. We have learned a lot from our investigation of the Butte Fire entrapments and want firefighters to know about the role the fire shelter played and how they can increase their chance of survival.

What the Shelter Can and Can't Do

The fire shelter protects primarily by reflecting radiant heat. As demonstrated on the Butte Fire, even large cracks or tears do not reduce the shelter's protective capabilities when radiant heat is the principal hazard. Several people on that fire deployed shelters with 4- to 18-inch tears. These shelters let in some smoke but still protected their occupants from radiant heat and heavier concentrations of smoke.

The shelter's thin aluminum-glass cloth laminate can withstand only limited contact with flames. Cracks, tears, or holes reduce its protection in direct flames. The shelter should be deployed away from fuel concentrations—both natural fuels and flammable equipment.

Techniques for Survival

Avoid Entrapment—Experienced firefighters know the best way to ensure their safety on a wildfire is to avoid entrapment. But when drought conditions and severe fire weather combine, as they did on the Butte Fire, avoiding entrapment is not always possible. Several people we interviewed said that before being trapped on the Butte Fire, they felt they would never let themselves get into such a situation and need a fire shelter.

We estimate that the fire shelter has saved more than 140 lives since its introduction ....

Although entrapment can't always be avoided, you can make it unlikely by:

- Following the 10 Standard Firefighting Orders.
- Knowing the 13 fire situations that shout "Watch Out!"
- Knowing the four major common denominators of fire behavior that lead to tragedy or near-miss fires.

Use the fire shelter as a last resort. Follow proven escape procedures first.

Select Safety Zones Carefully—The large safety zones on the Butte Fire minimized direct flame contact on the shelters, allowing them to perform effectively and reflect radiant heat as they were designed to do.

First, select safety areas carefully. Next, look for natural protection within the safety zone and use it. Erect the shelter behind a large rock, dozer blade, or other heat shield. Take advantage of constructed or natural depressions or small earth berms. On roads, deploy in the cut slope ditch. Such spots expose you and your shelter to less heat, smoke, and wind.

Commit Yourself to the Shelter—When you know you can't escape entrapment, commit yourself to the shelter. Deploy it quickly. Use any extra time to pick the best spot and prepare the site by scraping away flammable fuels. Keep an arm or leg through one of the shelter straps. Otherwise, you might lose the shelter in the high winds the flame front generates. A survivor of the Butte Fire—a veteran of 23 fire seasons—estimated winds at 50 to 70 miles per hour.

The coolest, cleanest air is within a few inches of the ground. So stay low with your nose pressed to the earth.

Once inside the shelter, stick it out no matter how scared you are or how painful it is. Remember, it is always much better inside the shelter than outside. If you make a dash for it, your chances of survival are poor. If you leave after the flame front passes but while it's still smokey, you risk injury from smoke inhalation. It's best to stay put until a crew leader says it's safe to leave.

Maintain Communications—The entrapment reports we've studied show the psychological benefits of reducing fear and panic by talking to trapped coworkers directly or by radio. If you can't talk on the radio, listen. Outside observers may be able to provide valuable information about the fire in your location. At its peak, the noise of a fire can be deafening, and you may not be able to hear anyone. Don't panic. As soon as the noise subsides, resume communications.

Role of Other Equipment— Recent fire entrapments illustrate the value of flame-resistant clothing. This clothing protects you while you're escaping entrapment or deploying and occupying a shelter. Be sure to wear gloves. Butte Fire experiences show that holding the shelter down can be a major problem in high winds. Without gloves you may burn your hands and not be able to hold the shelter down. We hope to improve shelter hold-down features in future designs. Wear your hardhat, equipment packs, and other gear inside the shelter to help keep hot surfaces away from your body. Be sure to leave tools, which can cut shelter cloth, outside. Any gasoline or fusees should be left behind or thrown far from any shelter.

In larger safety areas, you may want to move the shelter to get away from heat concentrations. This tactic was effective on the Butte Fire. However, firefighters reported that as they moved the shelters were hard to hold onto, allowing smoke to get inside. *Remember, if you move, there is the danger of exposing your face to hot flames and gases.*

Shelter Training—The more you know about the fire shelter and what to expect during entrapment, the better prepared you'll be should it happen. A new film, "Your Fire Shelter;" is a good place to begin. Study the pamphlet of the same title carefully. Practice the imaging techniques, then get hands-on training by deploying obsolete shelters. Refer to the pamphlet for training recommendations.

Care and Inspection— Experiences during the past several years have shown why proper shelter care and inspection are vital. Many shelters deployed on the Butte Fire had cracks along the fold lines. Most shelters with this type of damage should be screened out in a proper inspection program. The pamphlet "Your Fire Shelter" contains details on care and inspection.

The events of the 1985 fire season have reaffirmed the worth of the fire shelter and the wisdom of having every firefighter carry one on the line. Entrapment experiences made believers out of many firefighters during this past fire season. Learn from their experience—find out as much as you can about how to use, care for, and inspect the fire shelter. This know-how could save your life someday. ■

Shelter Use Observations

1. Fire shelters work, even when they are not in the best condition. Some shelters used in the Butte Fire had 4- to 18-inch tears along folds.

2. In indirect attack situations, safety zones should be constructed to provide effective backup if alternative escape routes are cut off or early evacuation is not possible.

3. Safety zones on ridge tops should be at least 300 feet in diameter in timber with fuel model G or 10. They may have to be larger in other locations.

4. The value of competent, well-trained, and experienced crew bosses, strike team leaders, and division supervisors cannot be overemphasized. In the Butte Fire incident, many lives were saved through their actions.

5. Overhead should recognize that firefighters using shelters may not be able to use their radios if turbulent conditions make it difficult to hold the shelter in place. On the other hand, one-way communications should continue to give instructions and reassurance. It will be a challenge to overhead to effectively communicate reassurances to sheltered firefighters while still transmitting key information regarding the nature of a major incident.

6. When in shelters, firefighters should continue to talk to one another to maintain contact and reduce the chance of panic.

7. Once the fire has passed over, firefighters should stay in their shelters until the smoke has cleared.

8. Sheltered firefighters should not wet down their skin or clothing or wet handkerchiefs for breathing. Moist heat causes more damage to lung tissues than dry heat.

9. Sheltered firefighters should sip water to prevent dehydration.

10. Incident commanders, operation section chiefs, and emergency medical technicians should follow up after an incident to ensure that those involved in the shelter deployment are in the proper physical and mental condition to continue in their fire assignments. A delayed stress response following a traumatic incident could seriously impair the safety and productivity of fireline personnel.

11. The life-saving value of shelters should be ensured through proper care and handling by firefighters. Throwing shelters around, sitting on them, or other rough treatment will accelerate the development of tears and holes.

12. Missoula Equipment Development Center's field trial publication "Your Fire Shelter" (August 1984) contains the most up-to-date information on fire shelter use and inspection. All firefighting personnel should carefully review this publication. The publication includes information on entrapment and on deployment, inspection, and care and handling of the shelter.

13. Measures need to be taken to ensure that all firefighters know how to deploy and use the fire shelter. Contract sawyers, dozer operators, National Guard truck drivers, and other involved persons should be instructed as well.

Richard C. Rothermel and Robert W. Mutch

Methods for Predicting Fire Behavior— You Do Have a Choice

Patricia L. Andrews

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Predictions of wildland fire behavior are used in various aspects of fire management: prescribed fire planning, presuppression planning, real-time fire suppression activities. Methods for calculating fire behavior covered here represent continued improvement of the packaging of mathematical prediction models for use by fire managers. Such improvement resulted from expanding user needs, additional research results, and new technology. Options available to managers range from manual methods (such as tables and nomograms), to handheld calculators, to computers. These methods mainly differ in prediction capabilities and ease of use. It is important to understand that although the methods may differ, all produce valid results.

Figure 1—*Fire behavior predictions can be made using manual methods (such as nomograms or tables), the TI-59 and HP-71B calculators, or the BEHAVE fire behavior prediction and fuel modeling system.*

In this article I will discuss the manual methods described by Rothermel in "How To Predict the Spread and Intensity of Forest and Range Fires" *(15)*, the TI-59 calculator with a CROM (Custom Read Only Memory) *(8)*, the HP-71B calculator with a CROM *(18)*, and the BEHAVE fire behavior prediction and fuel modeling system *(6, 7)* (fig. 1).

Computer programs not nationally available to all agencies and private firms, such as FIREMOD *(1)* and FIRECAST *(12)*, will not be discussed here. In addition, I have included only those methods that predict site-specific fire behavior. This discussion, therefore, does not include systems designed for other purposes, the National Fire Danger Rating System, for example. I will not cover the role and importance of experience, except to emphasize that it is vital to any method of predicting fire behavior.

Manual Methods

Manual methods for calculating fire behavior include tables, graphs, and nomograms. Albini's nomograms for spread rate and intensity *(2)* were the first step in providing prediction models to the field. As Dick Rothermel stated in the preface to "How To Predict the Spread and Intensity of Forest and Range Fires," Frank Albini "let the genie out of the bottle with publication of his book of nomograms in 1976." Although that was 10 years ago, the nomograms remain useful in this age of computers. Nomograms graphically depict potential fire behavior, showing relationships that cannot as easily be seen in tables. Nomograms allow quick estimation of spread rate, flame length, and intensity, based on a minimum of information.

Rothermel *(15)* describes the nomograms and other manual methods for calculating fire behavior that have been developed through the S-590 Fire Behavior Analyst (FBA) course. Even with the availability of calculators and BEHAVE, S-590 con-

tinues to include the manual methods. An FBA should be proficient in all methods of calculating fire behavior (manual, calculator, BEHAVE, and, of course, experience), so as to be prepared to cope with contingencies such as battery failure or lack of electric power.

The S-390 Intermediate Fire Behavior course *(13)* also covers manual methods. So many students take S-390 that it would be impractical to require all of them to use a computer or calculator. In addition, the S-390 Field Reference can be readily used in the field. The reference has been nicknamed the "two-bit TI," meaning that it can do what the TI does, at less cost.

TI-59 Calculator

Developing a spread and intensity CROM for the TI-59 handheld calculator gave users a quick, easy, and handy means for calculating fire behavior predictions in the field as well as in the office. The automation was a major step beyond manual methods.

Additional fire behavior prediction programs for the TI-59 are available on cards *(4, 11)*. This calculator can process calculations too complex for manual methods. For example, the nomograms for maximum spotting distance are limited to spotting from a single torching tree on flat ground. The TI program allows for mountainous terrain and for spotting from a group of torching trees, burning piles, and wind-driven surface fires.

BEHAVE System

The next improvement after the development of the calculator was the BEHAVE fire behavior prediction and fuel modeling system *(6, 9, 16)*. BEHAVE is currently being expanded to allow additional prediction capabilities *(7)*. Anyone who has progressed from nomograms to the TI and then to BEHAVE can attest to the extent of the advancement. BEHAVE is not only the most comprehensive of the methods for calculating fire behavior, but it is also the easiest to use.

Many of the prediction models in BEHAVE were already available in the form of manual methods or TI-59 programs. BEHAVE also includes models not previously available. One of the major features of BEHAVE is the capability to design custom fuel models.

BEHAVE gathers the prediction models into one easy-to-use package. Tables of predictions can be generated quickly. For example, in a few minutes one can tabulate the effect of various windspeeds on rate of spread, whereas it takes days to build tables using the TI-59. In the office, BEHAVE is the logical choice for fire behavior calculations.

However, despite improved capability to access computers from remote sites, handheld calculators are still needed for predicting fire behavior in the field.

HP–71B Calculator

The HP–71B calculator is replacing the TI–59 calculator for fire behavior calculations *(10, 18)*. The TI-59's are breaking down and are no longer manufactured. Handheld calculator technology has advanced significantly since the adoption of the TI-59 and its CROM. So the HP is much more than a replacement. Its capabilities go far beyond those of the TI and are almost the same as BEHAVE.

The HP fire behavior program is patterned after the BURN subsystem of BEHAVE (the FIRE 1 and FIRE 2 programs). The design, keywords, and worksheets are similar insofar as is practical. I anticipate that people will frequently switch between BEHAVE and the HP. For example, in fire camp an FBA may have access to BEHAVE, but on the fireline will use the HP.

Calculation Comparison

Table 1 shows aspects of fire behavior that can be calculated, and alternative methods for doing so. For example, forward rate of spread, if upslope with the wind, can be calculated using tables, nomograms, BEHAVE, and the TI-59 and HP-71B calculators. Only BEHAVE and the HP-71B, however, can calculate rate of spread for any specified direction. Containment by indirect attack can be calculated only by BEHAVE; this is the only calculation that can be done by BEHAVE and not by the HP-71B. The table also indicates that BEHAVE provides the only means for designing custom fuel models; the

Table 1—*Major elements of fire behavior that can be predicted and various methods of calculation [Numbers in parentheses refer to publications in the literature cited section.]*

Fire behavior element	Manual methods	TI-59	HP-71B	BEHAVE
Rate of spread; flame length; fireline intensity:				
Upslope with the wind	Tables *(13)*, nomograms *(15)*	CROM *(8)*	CROM *(18)*	*(6)*
In the direction of maximum spread	vectoring *(15)*	—	CROM *(18)*	*(6)*
In any specified direction	—	—	CROM *(18)*	*(6)*
Heat per unit area	Nomograms *(15)*	CROM *(8)*	CROM *(18)*	*(6)*
Reaction intensity	Nomograms *(2)*	CROM *(8)*	CROM *(18)*	*(6)*
Area; perimeter:				
With upslope wind	Tables *(13, 15)*	CROM *(8)*	CROM *(18)*	*(6)*
With cross-slope wind	—	—	CROM *(18)*	*(6)*
Length-to-width ratio	Diagrams *(13, 15)*	—	CROM *(18)*	*(6)*
Forward spread distance	Multiplication *(15)*	CROM *(8)*	CROM *(18)*	*(6)*
Backing spread distance; maximum width of fire	—	—	CROM *(18)*	*(6)*
Maximum spotting distance:				
From torching trees	Nomograms *(15, 3)*	Card *(11)*	CROM *(18)*	*(6)*
From burning piles	—	Card *(11)*	CROM *(18)*	*(6)*
From wind-driven surface fires	—	Card *(11)*	CROM *(18)*	*(7)*
Containment (final fire size, line building rate, containment time):				
Direct attack	—	Card *(4)*	CROM *(18)*	*(6)*
Indirect attact	—	—	—	*(7)*
Scorch height	Graph *(2)*	—	CROM *(18)*	*(7)*
Probability of ignition	Tables *(13, 15)*	—	CROM *(18)*	*(7)*
Ignition component	—	CROM *(8)*	—	—
Fine dead fuel moisture	Tables *(13, 15)*	CROM *(8)*	CROM *(18)*	*(6, 7)*
Custom fuel models				
Develop	—	—	—	*(9)*
Use	—	Card *(9)*	CROM *(18)*	*(6)*

fuel models can then be used on the TI and HP.

Some factors related to individual predictions deserve further discussion. All methods for predicting fire behavior are based on Rothermel's spread model *(14)*. Therefore, given the same input, the predicted rate of spread will be the same whether the calculations are done using a nomogram, table, calculator, or computer.

Table 1 indicates that fine dead fuel moisture can be calculated using tables, the TI-59 CROM, the HP-71B

CROM, and BEHAVE. Nevertheless, there are major differences in the methods. The TI-59 estimates fine dead fuel moisture based on temperature, relative humidity, and shade. It should be used only as a last resort. The S-590 tables allow adjustment for other factors: aspect, slope, position on the slope, and time of day. The S-390 tables are a modification of, and produce results similar to, the S-590 tables. The prediction model implemented on the HP-71B and in BEHAVE is a highly sophisticated site-specific model *(17)*. The different input required for each of the models should tell the user that the models are indeed different.

The models used to predict factors other than fuel moisture are not dramatically different. Answers may be slightly different, but not significantly so, when one considers the application and the resultant decisions. In most cases input and output are the same. The differences lie in the internal workings of the mathematical model.

The vectoring method for predicting spread under cross-slope wind conditions includes some simplifying assumptions that permit the use of manual methods. More sophisticated calculations are done in BEHAVE and on the HP.

The area and perimeter calculations for the tables and the TI are based on a double-ellipse formula *(5)*, whereas BEHAVE and the HP use a simple elipse. The results are slightly different. This modification made it possible to link size calculations to containment calculations and to predict fire behavior in a cross-slope wind.

The containment calculations for the TI, HP, and BEHAVE are all slightly different. The TI model had limitations and discontinuities that were overcome for the BEHAVE version. The HP requires a tabular version of the model in BEHAVE because of the number of calculations involved.

Probability of ignition is the same for the tables, the HP, and BEHAVE. (The S-390 table is a condensation of the S-590 table.) Through oversight, ignition component rather than probability of ignition was put on the fire behavior part of the TI CROM. Ignition component was developed for use in the National Fire Danger Rating System; probability of ignition is used for fire behavior prediction.

Summary

Methods for estimating fire behavior vary from manual calculations to computer programs. Manually calculated predictions are subject to many limitations, and one must be highly trained to use them. Nevertheless, manual calculations will always remain useful, especially for a fire behavior analyst on a wildfire suppression overhead team. Those who need fire behavior predictions at a specified time will not accept the excuse of equipment failure. And when tailgate predictions of fire behavior are called for, a quick look at a nomogram should suffice.

Even with the availability of manual methods and BEHAVE, there has been overwhelming demand to replace the TI-59. Because of advances in technology, the HP-71B CROM has capabilities far beyond those of the TI-59 CROM. The HP-71B is very similar to BEHAVE, including a user-friendly interface. However, the availability of the HP-71B does not mean that each TI-59 should be replaced with an HP. Although the TI is capable of only about 10 percent of what the HP can do, if that 10 percent meets your needs and your TI is still working, there is no urgent need to immediately switch to the HP. The predictions from the TI are as valid as ever.

BEHAVE is at the automated end of the methods scale. It has the most capabilities and is the most user-friendly alternative. In most cases BEHAVE is the preferred choice; however, access to a computer is not always possible. Although predictive capabilities increase in the progression from manual methods to calculators to BEHAVE, each method for calculating fire behavior has its own niche in fire management activities. You are now fortunate enough to have a wide choice in the method that you use to calculate fire behavior. ■

Literature Cited

1. Albini, F.A. Computer-based models of wildland fire behavior: a users' manual. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1976. 68 p.
2. Albini, F.A. Estimating wildfire behavior and effects. Gen. Tech. Rep. INT-30. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1976. 92 p.
3. Albini, F.A. Spot fire distance from burning trees—a predictive model. Gen. Tech. Rep. INT-56. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1979. 73 p.
4. Albini, F.A.; Chase, C.H. Fire containment equations for pocket calculators. Res. Note INT-268. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 17 p.
5. Anderson, H.E. Predicting wind-driven wildland fire size and shape. Res. Pap. INT-305. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983. 26 p.
6. Andrews, P.L. BEHAVE: Fire behavior prediction and fuel modeling system—BURN subsystem, Part 1. Gen. Tech. Rep. INT-194. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986. 130 p.
7. Andrews, P.L.; Chase, C.H. BEHAVE: Fire behavior prediction and fuel modeling system—BURN subsystem, Part 2. Gen. Tech. Rep. INT-000. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; [in press].
8. Burgan, R.E. Fire danger/fire behavior computations with the Texas Instruments TI-59 calculator: user's manual. Gen. Tech. Rep. INT-61. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1979. 25 p.
9. Burgan, R.E.; Rothermel, R.C. BEHAVE: Fire behavior prediction and fuel modeling system—FUEL subsystem. Gen. Tech. Rep. INT-167. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 126 p.
10. Burgan, R.E.; Susott, R.A. HP-71 replaces TI-59 for fire calculations in the field. Fire Management Notes. 47(2): 9–11.
11. Chase, C.H. Spotting distance from wind-driven surface fires—extensions of equations for pocket calculators. Res. Note INT-346. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 21 p.
12. Cohen, J. FIRECAST user's manual. Riverside, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, Forest Fire Laboratory; [in press].
13. National Wildfire Coordinating Group. Fire behavior self-study course. S-390. Boise, ID: Boise Interagency Fire Center; 1981.
14. Rothermel, R.C. A mathematical model for fire spread predictions in wildland fuels. Res. Pap. INT-115. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1972. 40 p.
15. Rothermel, R.C. How to predict the spread and intensity of forest and range fires. Gen. Tech. Rep. INT-143. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983. 161 p.
16. Rothermel, R.C. BEHAVE and YOU can predict fire behavior. Fire Management Notes. 44(4): 11-15; 1983.
17. Rothermel, R.C.; Wilson, R.A., Jr.; Morris, G.A.; Sackett, S.S. Modeling moisture content of fine dead wildland fuels: input to the BEHAVE fire prediction system. Res. Pap. INT-359. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986. 63 p.
18. Susott, R.A.; Burgan, R.E. Fire behavior computations with the Hewlett-Packard HP-71B calculator. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; [in press].

HP–71 Replaces TI–59 for Fire Calculations in the Field

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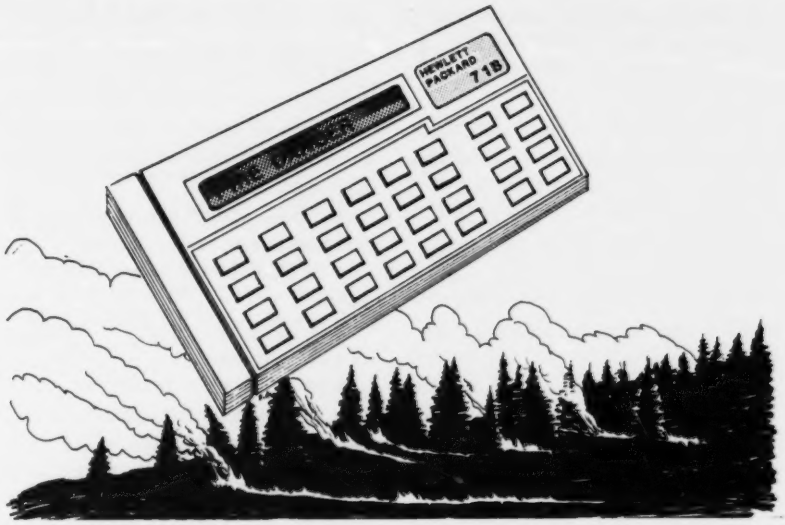
If your Texas Instruments TI–59 is nearing its last gasp, you can replace it with a newer calculator and enjoy the use of improved fire danger and fire behavior programs. The Hewlett-Packard HP–71B handheld calculator has been selected to replace the TI–59 and is now available on a USDA Forest Service contract.

The HP–71B has several features that make it attractive as a field calculator:

- An alphanumeric display that eliminates the need for keyboard overlays.
- A liquid crystal display (LCD) that becomes easier to read in daylight, rather than more difficult.
- Use of complementary metal oxide semiconductor (CMOS) technology, which has a very low power requirement, thus permitting 2 to 3 months of normal use between battery changes.
- Field-replaceable AAA batteries, rather than rechargeable nickel-cadmium batteries.
- A continuous memory that retains the information stored in the calculator even when it is turned off.
- A computational speed about six times faster than the TI–59.
- A capability to be used with optional battery-operated printers, data cassettes, and disk drives.
- A powerful BASIC programming language that is available for many other applications.
- Output that can be routed to a battery-operated, field-portable Hewlett-Packard inkjet printer.



The HP–71B has several features that make it an effective field calculator.

The National Fire Danger Rating System (NFDRS) program and the fire behavior program have been put on separate Custom Read Only Memories (CROM's) for use in the HP–71B. Separate user's manuals have also been prepared for each program. The manual for calculating NFDRS indexes and components is "Fire Danger Computations with the Hewlett-Packard HP–71B Calculator." The fire behavior user's manual is "Fire Behavior Computations with the Hewlett-Packard HP-71B Calculator." Both manuals are soon to be published by the Intermountain Research Station *(2, 4)*. Separate self-study guides have been prepared for the fire danger and fire behavior programs and are available through the agency coordinator.

NFDRS Program

The inputs required to perform 1978 NFDRS *(3)* computations are the same as for the TI–59 and other systems. Weather inputs may be recorded on the Weather Service's "10-Day Fire Danger and Fire Weather Record" form D–9b or on the form provided in the user's manual.

The major attributes of the NFDRS program are:

- Computes NFDRS indexes and components from weather inputs when the program's WEATHER module is selected.
- Automatically updates and stores the values of those inputs that must be carried forward from day to day. When the WEATHER module is used, these values do not need to be manually reentered each day.
- The NFDRS fuel models are stored in the calculator, not on magnetic cards.
- Up to five supplemental "user defined" NFDRS fuel models may also be permanently stored in the calculator memory, although no method currently exists for building and testing such models.

Fire Behavior Program

The fire behavior program, which is patterned after the BURN subsystem of BEHAVE *(1)*, implements much more fire behavior technology than was possible with the TI–59. Program capabilities are indicated by the following list of program modules and their functions:

- FUEL MODEL—permits inputting, loading, listing, saving and deleting models, and listing names of models stored in the calculator.
- DIRECT—calculates spread rate, heat per unit area, fireline intensity, flame length, reaction intensity, effective windspeed, and direction of maximum spread.
- SIZE—calculates area, perimeter, length-to-width ratio, forward spread distance, backing spread distance, and maximum fire width.
- CONTAIN—calculates length of fireline at containment time, time to containment, and final fire size or line building rate required to stop the fire at a specified size.
- SPOT—calculates maximum spotting distance.
- SCORCH—calculates scorch height.
- IGNITE—calculates probability of spot fire ignition.
- MOISTURE—calculates 1-hour timelag fuel moisture, fuel level temperature and relative humidity, percentage of area shaded, and probability of ignition for a specific burn time or on an hourly basis.
- MAP—calculates fire dimensions or spotting distance for plotting on a map.
- SLOPE—calculates slope steepness, elevation change, and horizontal distance between two points.
- WIND—calculates midflame windspeed from 20-foot windspeed.
- RH—calculates relative humidity and dew point from dry bulb and wet bulb temperatures and elevation.
- TWO—calculates weighted rate of spread for the two-fuel model concept.

Up to 19 user-defined fire behavior fuel models may be stored in the calculator, in addition to the 13 standard models that are always available. Output may be produced as a list of one to three values for each output item or up to a 3-by-3 matrix of output values for a single output item. Program modules can be linked as in the BEHAVE system, to easily pass outputs from one module to another for additional calculations. The program will accommodate either English or metric inputs and outputs.

Purchasing

The HP–71B calculator, fire danger CROM, and fire behavior CROM have been placed on contract for the following agencies: USDA Forest Service; USDI Bureau of Land Management, Bureau of Indian Affairs, National Park Service, Fish and Wildlife Service; and State Forestry agencies. Orders should be placed with:

Government Marketing Services, Inc.
701 E. Gude Drive
Rockville, MD 20850
Attn: Art Phillips

The original and one copy of the order must be sent to Government Marketing, and the order must state the contract number: 54–3187–5–35. Contract prices are:

Calculator	$349.12
Fire Danger CROM	37.80
Fire Behavior CROM	58.80

Those not authorized to purchase from this contract can order HP–71's and CROM's from Government Marketing at commercial prices.

The appropriate battery-operated printer is the HP "Think-jet" printer, model 2225B. The printer is not required for effective use of the calculator in the field because the user's

manuals include forms for recording inputs and outputs. The printer is almost a necessity, however, if the user plans to write other programs for the HP–71B. Ease of programming and filing capabilities suggest that many useful programs can be added to the HP–71B calculator. ■

Literature Cited

1. Andrews, Patricia A. BEHAVE Fire behavior prediction and fuel modeling system—BURN subsystem, Part 1. Gen. Tech. Rep. INT–194. Ogden, UT: U.S. Department of Agriculture, Forest Service Intermountain Research Station; 1986. 130 p.
2. Burgan, Robert E.; Susott, Ronald A. Fire danger computations with the Hewlett-Packard HP–71B calculator. Gen. Tech. Rep. INT–000. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986. [in press]
3. Deeming, John E.; Burgan, Robert E.; Cohen, Jack D. The national fire-danger rating system—1978. Gen. Tech. Rep. INT–39. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1977. 63 p.
4. Susott, Ronald A.; Burgan, Robert E. Fire behavior computations with the Hewlett-Packard HP–71B calculator. Gen. Tech. Rep. INT–000. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986. [in press]

Behavior of the Life-Threatening Butte Fire: August 27–29, 1985

Richard C. Rothermel and Robert W. Mutch

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On August 29, 1985, 73 firefighters were forced into safety zones, where they took refuge in their fire shelters for 1 to 2 hours while a very severe crown fire burned over them. The incident took place on the Butte Fire on the Salmon National Forest in Idaho. Five firefighters were hospitalized overnight for heat exhaustion, smoke inhalation, and dehydration; the others escaped uninjured. Investigators estimated that without the protection of the escape zones and the fire shelters, at least 60 of the 73 firefighters would have died. Thanks to preparation of safety zones, the effectiveness of the fire shelters, and the sensible behavior of the firefighters themselves, disaster was averted.

Behavior of the Butte Fire, particularly its explosive movement on the afternoon of August 29, is of vital interest to fire behavior specialists, individual firefighters, and leaders who make tactical decisions based on fire behavior projections. That an already large and intense fire could rapidly escalate to even higher intensity—some have called it a firestorm—and move fast enough to overrun 73 firefighters warrants review by anyone concerned with fire management.

Immediately after the shelter incident, a review team was dispatched to the Butte Fire to document the meteorological conditions and fire behavior that contributed to the life-threatening run up Wallace Creek. Results of the analysis were distributed to all wildland fire management agencies early the following week. The review team was composed of Dennis Martin and Hank Walters, Forest Service Intermountain Region; Clyde O'Dell, National Weather Service; Dick Rothermel, Intermountain Fire Sciences Laboratory; and Bob Mutch, Forest Service Northern Region. The purpose of this article is to augment and expand the results of the initial review through additional interviews with those who had been on the fireline and an analysis of photographs taken during and after the fire run. Art Jukkala and Ted Putnam of the Missoula Equipment Development Center have also prepared a report on the performance of the fire shelter based on many interviews with those who used it on the Butte Fire. The article "Forest Fire Shelters Save Lives" in this issue includes information on their findings.

A separate review of the Butte Fire and adjacent fires in the Salmon River (termed the Long Tom Complex), conducted by the Forest Service Intermountain Region in October 1985, examined such topics as strategy, tactics, and other issues. The results of this review are on file in the Forest Service regional office in Ogden, UT.

Fire Environment

Severe drought characterized weather in the Butte Fire area throughout the summer of 1985, contributing to critically low fuel moisture levels. The fire weather station at nearby Indianola along the Salmon River measured only 0.31 inch of precipitation in June and 0.23 inch in July. Although more than half an inch of precipitation fell on two different days in early August, some of this as snow, only 0.12 inch fell between August 13 and August 31. At a remote automatic weather station near the fire, 1,000-hour fuel moisture readings from the National Fire Danger Rating System were rated at 8 percent prior to the run up Wallace Creek.

The weather on the Butte Fire from Monday, August 26, through Friday, August 30, was not unusual considering the location. Elevation at Base Camp was 7,400 feet; elevations on the fire ranged from 6,400 feet near the confluence of Wallace and Owl Creeks to 8,200 feet near the two safety zones. Typical late afternoon maximum temperature reached 70 to 78 °F, with minimum relative humidity in the 12 to 21 percent range at Sourdough Base Camp. The windiest period each day occurred between 1400 and 1500 mountain daylight time. The velocity was generally between 10 and 12 miles per hour, with stronger gusts. Inversions occurred each day, breaking between 1130 and 1330.

Weather on the day of the blowup, August 29, was not unusual, either. In the afternoon the temperature reached the mid-70's, and minimum relative humidity was in the upper teens. At base camp, low-level winds were out of the south at 8 to 12 miles per hour in the afternoon, with occa-

sional gusts to 17 to 20 miles per hour. District personnel reported that fuel loadings ranged from 80 to 100 tons per acre in spruce-fir stands in drainage bottoms, to 25 to 40 tons per acre in higher elevation lodgepole pine-fir stands. Fuel models 8 and 10 characterized most of the Wallace Creek drainage.

One unusual feature of the area threatened by fire was the topography. The upper slopes did not converge into sharp peaks as is commonly the case in the Rocky Mountains, but tended to be domelike, with continuous crown cover. Wallace Creek itself was a well-defined north-south drainage that became progressively steeper at its headwaters near the two shelter sites.

General Fire Behavior

The Butte Fire was started by lightning on July 20, 1985. This fire was part of the Long Tom Fire Complex in the Salmon River drainage, which included the Corn Lake, Bear, Fountain, Goat Lake, and Ebenezer Fires. The Butte Fire was first contained on August 5 at just over 20,000 acres. Strong winds fanned smoldering fuels and spread fire across control lines on August 24 and 25. Fire activity peaked on August 27, 28 and 29, as the fire made runs of 1,000, 2,000, and 3,500 acres, respectively. About 3,000 of the 3,500-acre growth on August 29 reportedly occurred in about 90 minutes. It was during this run up Wallace Creek that the 73 firefighters deployed their fire shelters. Simultaneously, another run of lesser severity occurred in Owl Creek, the drainage east of Wallace Creek. Both columns were characterized by dense black smoke. By midafternoon the Wallace Creek column had reached 15,000 to 17,000 feet above terrain and had a firm cumulus cap. Another area of intense fire activity took place on the western flank where the fire spread northward but was apparently pulled into the main fire in Wallace Creek.

Events of August 29

On August 29 wind velocities were not especially high. In the early afternoon, eye level winds were measured at 7 to 8 miles per hour at the confluence of Owl Creek and Wallace Creek. At the higher elevation near the head of Wallace Creek, the local winds were stronger. Division Supervisor Jim Steele estimated winds to be 10 to 15 miles per hour, with gusts to 20 miles per hour across the ridges. Measurements nearby confirmed this estimate, but with gusts of 25 to 30 miles per hour.

Figure 1 shows the fire area at 0200 in the morning on August 28, the day before the big run, and its extent by 2200 in the evening. By 0200 in the morning of August 29, the fire had spread considerably further, having crossed the lower end of Wallace Creek and moved up the ridge toward Owl Creek. The burned areas in lower Wallace Creek were patchy. Of special importance on the morning of August 29 were the spot fires in the middle portion of Wallace Creek and along Owl Creek at the southeast corner of the fire.

An understanding of the fire control operations is essential to understanding many events during the 29th. Having had little success at close-in direct attack on the 26th and 27th, the overhead team had decided to use an indirect attack strategy. On the 28th and 29th, a tractor line was built along the main ridge on the north end of the fire, approximately 1.5 miles north of the nearest spot fires in Wallace Creek (fig. 1). Fortunately, the line construction included several safety zones 300 to 400 feet in diameter at approximately 1/4-mile intervals. The plan for the 29th was to conduct a burnout operation in the late afternoon when humidity was expected to rise. An aerial drip torch would be used for center firing in the upper end of Wallace Creek. Crews were to be dispersed along the line to burnout from the line after a convection column was developed.

During the morning of August 29, spot fires near the confluence of Wallace and Owl Creeks threatened valuable timber and seemed to have the potential to outflank the control line to the east. Thus, it was decided to use the helitorch early in the day to burn out and stabilize the line in this area. Initial attempts began just to the north of Owl Creek (marked A on fig. 1) about 1200. The area did not burn very well, and ignition attempts were repeated. Bill Williams, the operations chief, reported that this fire was ineffective at developing a significant

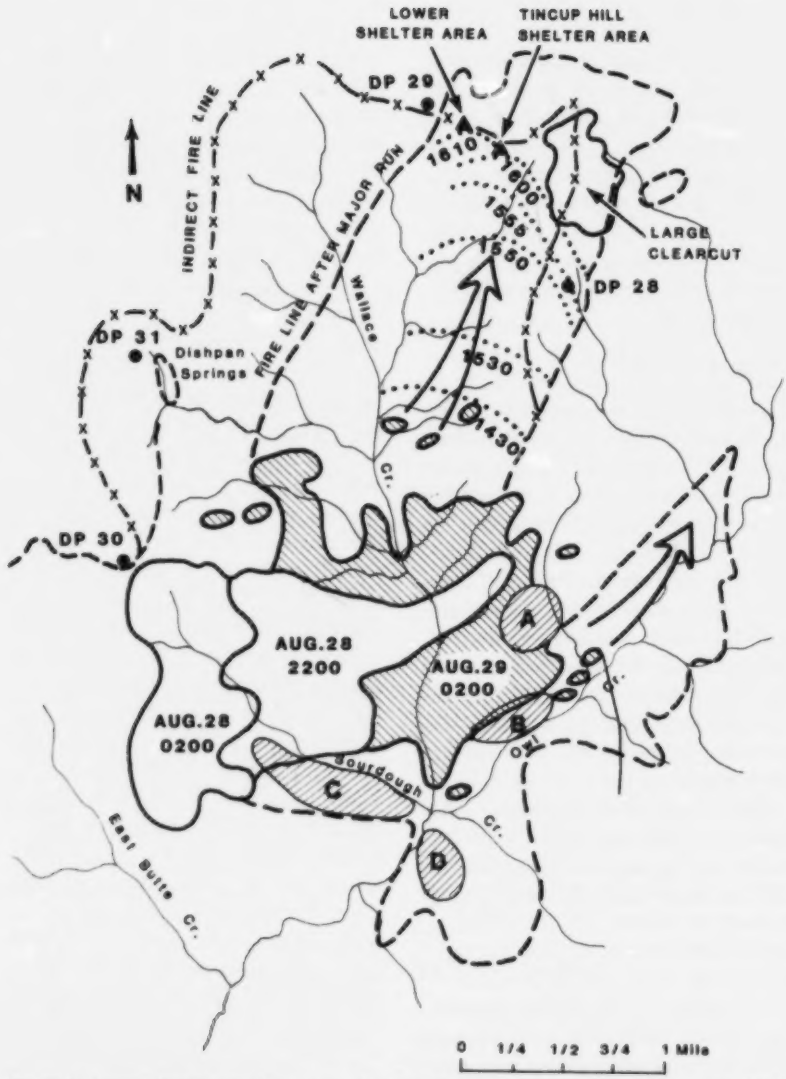


Figure 1—*Arrows depict major fire runs on the Butte Fire during the afternoon of August 29, 1985. The 73 firefighters deployed fire shelters at the lower shelter area and Tin Cup Hill shelter area. Areas A, B, C, and D indicate where the helitorch burnout operation was conducted that afternoon.*

fire column necessary for improving the fireline.

While attempts to burn out line near Owl Creek were in progress, the fire was developing strength in lower Wallace Creek. Three reports substantiate the development of fire in Wallace Creek. Bill Williams reported a large convection column east of Dishpan Springs. Dave Broberg, division supervisor in Owl Creek, reported two strong columns developing, one near drop point 30 at the upper end of Sourdough Creek and the other east of Dishpan Springs. Gary Orr, the division supervisor on the west side at drop point 30, saw the fire east of him throwing firebrands into Wallace Creek. Orr reported that the fire in this area was becoming active around 1100.

The spots along Owl Creek also became active and developed a strong convection column by 1300 (fig. 2). Smoke from these spots and from the helitorch fire was moving to the north. It appeared to some that these columns were being pulled to the north by the larger column developing to the northwest. With the aid of indrafts to these columns, the helitorch was used to burn out hand line and dozer line in areas C and D near the confluence of Sourdough and Owl Creek.

Meanwhile, Gary Orr at drop point 30 reported lots of fire in lower Wallace Creek. Considerable red coloration could be seen in the smoke columns, and at 1300 or 1400 the fire

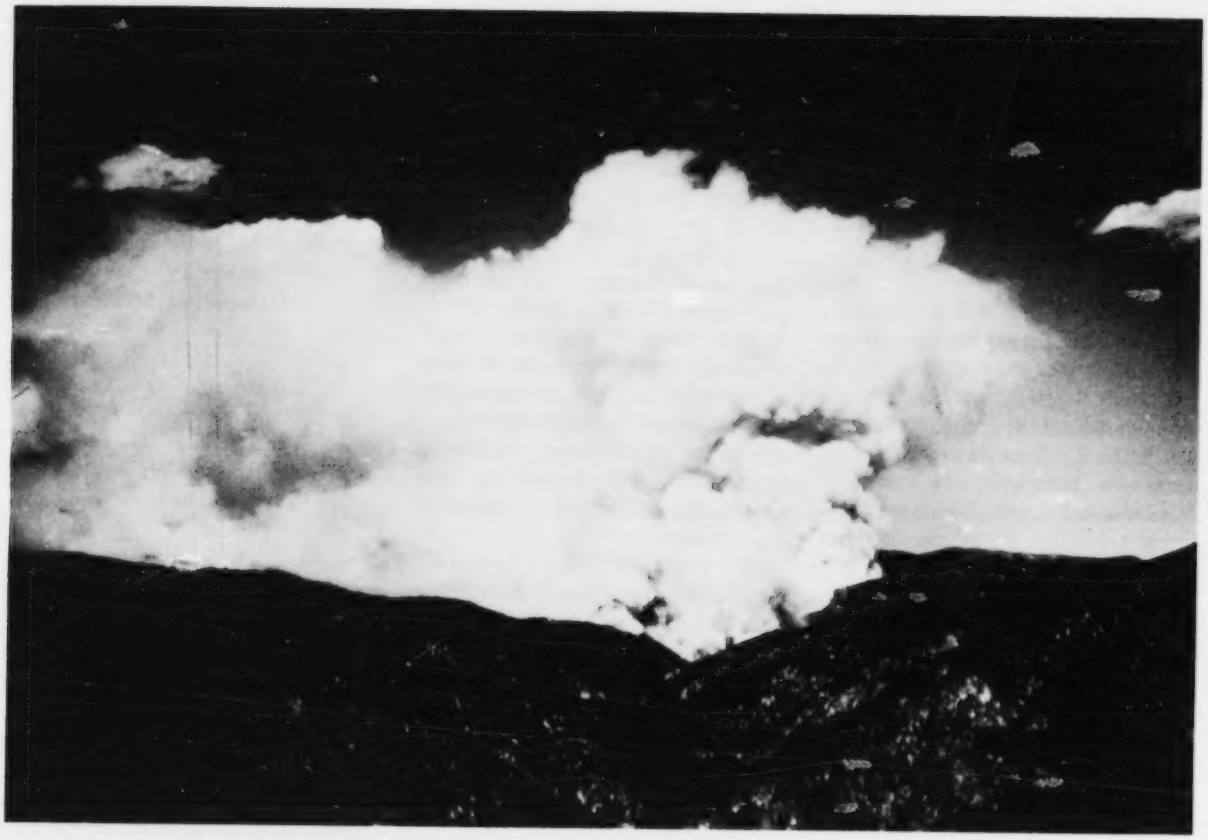


Figure 2—*Convection column development near the confluence of Sourdough, Wallace, and Owl Creeks at about 1515 m.d.t. on August 29. These columns originated from spot fires and helitorch operations.*

was intensifying and moving up Wallace Creek.

The helitorch continued burning out the line in area C. Later, at approximately 1500, area D was burned according to Bill Williams and Dave Broberg. Photographs looking north taken from a helicopter just to the south of the convergence of Sourdough, Wallace, and Owl Creeks (fig. 2) show the smoke columns building at about 1515. From this vantage point, the strongest column was from the burnout operation and spots in Owl Creek. All of the smoke was moving northward up Wallace Creek. The firing operation at the south end of the fire was completed successfully about 1550, and the fire was contained along the southern line just as it was reaching full strength in upper Wallace Creek.

Wallace Creek Run

About 1515, Jim Steele, at the northeast end of the fire, who later

went into his shelter at Tin Cup Hill, reported that he was walking on the trail above the large clearcut and could see fire coming up over a ridge to the south. He reported that at that time he could not see fire in Wallace Creek because of intervening smoke and trees. The fire he saw to the south was probably coming out of Owl Creek.

Bill Williams reported that about this same time a large, strong convection column was standing over the fire. This column was within the main northern dozer line, and Bill still hoped to use indrafts from the column to complete the planned burnout in upper Wallace Creek. Because a very severe crown fire started moving to the north up Wallace Creek on a western exposure (the east side of Wallace Creek) through extremely heavy fuels, the helitorch was never used in this area as originally planned.

Gene Benedict, the incident commander, was returning to the fire by helicopter between 1500 and 1515 and reported that "while viewing this fire I had three other convection columns in view: Goat Creek on the Salmon National Forest, Hand Meadows on the Payette National Forest (a new start), and a fire on the Nezperce near Cotter Bar. All fires were extremely active with apparent strong convective activity and substantial rates of spread, except for Goat Creek, which was topographically confined."

After landing, Gene received reports that the fire in Sourdough Creek had moved into Wallace Creek and had started a firestorm.[1] Initial reports said it covered about 2 miles in 15 minutes. (This later proved to be an overestimation.) Right after the major run, a second run started on the west side near drop point 30, apparently outside the dozer line. Initially, it spread rapidly to the north, but then veered to the east, probably due to indrafts from the larger column in Wallace Creek. This secondary run threatened firefighters along the line on the west side, who were evacuated by pickup truck and helicopter. Although this rescue was overshadowed by the fire shelter deployment, it was nevertheless an intensive effort accomplished safely.

Neal Davis, air attack supervisor, flew by helicopter around the fire just after 1400 and again at 1515. He provided estimates of the fire location in Wallace Creek before the fire developed the extreme behavior reported later. On his next flight, at 1550, Neal saw the firefighters in the safety zones preparing to go into their shelters.

Firefighter Steve Karkanen, working between drop point 28 and the large clearcut at the head of Wallace Creek, recorded the movement of the crown fire as it progressed up Wallace Creek. Steve took color photographs of the fire, recording his location, the direction he was shooting, and the estimated time and location of the fire front. His notes were especially helpful in reconstructing the fire movement. His notes at 1600 describe the nature of the fire as it passed around the large clearcut:

> Experiencing intense heat and high winds from all directions. At least three large whirlwinds passed over that were strong enough to knock people off balance. The area became too smoky and dusty to take photos. The smoke column completely enveloped everyone, and it was impossible to see the fire. Visibility was reduced to zero several seconds at a time, the air was very hot, and the area was showered with burning embers. Personnel within the clearcut did not take to their shelters, a dozer was used to build fireline around the vehicles, and the pumper crew worked on small spot fires in flashy fuels.

Personnel at the lower shelter area reported that the fire reached them at 1610. Jim Steele reports that the firefighters on Tin Cup Hill went into their shelters approximately 10 to 12 minutes before those in the lower area did. This would have put them in their shelters at just about 1600, or a couple of minutes before. Steele further reports that the fire approached them at about 1545 out of a draw to the southeast. While Steele was preparing to get into his shelter, he talked by radio to Strike Team Leader Ron Yacomella at the lower shelter

[1]Although referred to as a firestorm, it should more properly be called a conflagration, which is a severe spreading fire. The term "firestorm" is normally used to describe a severe stationary fire or burnout of an area within a conflagration.

area approximately 1,000 feet away. Ron asked if he should start his backfire at this time, which he did. His crew burned out approximately 200 feet in front of the lower shelter zone before the fire hit at 1610. Their backfire started easily. At first strong indrafts pulled the fire and smoke toward the fire front, but later the smoke blew back over the crew.

Table 1—*Behavior of Wallace Creek fire run on the afternoon of August 29, 1985*

Time period	Elapsed time	Distance	Rate of spread	
	min	*mi*	*mi/hr*	*ch/hr*
1430–1530	60	0.32	0.32	26
1530–1550	20	0.48	1.45	116
1550–1555	5	0.29	3.48	278
1555–1600	5	0.14	1.68	134
1600–1610	10	0.15	0.90	72

The Nature of the Fire

From observations by Neal Davis, Steve Karkanen, Jim Steele, and Ron Yacomella, we have reconstructed the probable location and time of the fire front as it moved up Wallace Creek and overran the crews (fig. 1). The rate of spread during the run is derived by scaling the distances from the map at each time line.

It appears that up until about 1530, although crowning and developing strong convection columns, the fire behavior was similar to the behavior observed on the two preceding days (table 1). The spread rate was low, about ⅓ mile per hour. After 1530 the fire spread much faster, with an average rate of about 2 miles per hour and a maximum of about 3½ miles per hour. This period was described as a firestorm by observers. The fire had to travel slightly over 1 mile in half an hour to reach the safety zone. In order for the firefighters to reach the large clearcut from the lower safety zone, they would have had to begin the evacuation by 1530.

As with any fire, this one must have moved by surges, with some periods of little or no spread. The reconstructed spread rates are too coarse to show the surges and appear to be slower than the impression received by observers on the ground.

Jim Steele reported that on Tin Cup Hill, firefighters in their shelters were hit by three waves of fire, the first one from the southeast. The second one burned up the north side and then burned back towards them at about the same time as the people in the lower safety zone were going into their shelters. The third wave hit from the southwest. Each time they were hit by a new wave of fire, the firefighters moved, crawling along the ground inside their shelters searching for cooler areas of the safety zone. At one time they moved away from the dozer piles of slash that had been made during the clearing of the safety zone. After 40 minutes in their shelters, they came out, but dense smoke forced them back in again for another 30 minutes. The air entering the shelters around the lower edges was apparently remarkably free of smoke.

The fire that overran the crews was very large and very intense. Figure 3 shows the nature of the fire as it passed over the shelter and indicates the size of the column in comparison to the trees. In the original color slide, the convection column shows red coloration for hundreds of feet above the trees. The fire at this time was almost certainly an independent crown fire *(4)*.

Viewed from the front, the fire appeared as a wall of flame 200 to 300 feet high. Viewed from the air, ahead of the fire, the flames were estimated to be two to three times the tree height. The fire front was advancing as a typical standing flame with the base of the fire in the trees. The flames in the front were not seen to be rotating or turbulent. The smoke was rising sufficiently so that the flame could be seen clearly. The column rose nearly vertically, then tilted toward the north. The rear of the column was a turbulent, swirling mass, impressive in its extreme behavior.

After the run, aerial inspection of upper Wallace Creek revealed a large, intensely burned area in which all crown needles and smaller surface fuels were essentially gone. There

Figure 3—*A view of the fire as it reached upper Wallace Creek and overran the fire crews. The crews deployed their fire shelters in safety zones similar to those seen in the foreground. This photo was taken from a helicopter looking toward the east.*

was, however, no evidence from the air, or on the ground near the shelter sites, of firestorm activity such as that seen on the Sundance Fire in the Idaho Panhandle in 1967. Trees were not laid down in patterns that would indicate large firewhirl activity. Some firewhirls had been observed during the fire, but trees were not knocked down, uprooted, or broken off as they were in the Pack River Valley as a result of the Sundance Fire.

Inside the Fire Shelters

That all the firefighters in the escape zones survived without serious injury borders on the miraculous. Nevertheless, the approach and passage of the fire was a terrifying ordeal. Many, in fact, doubted that they would live through it. The trauma of the event was reflected in interviews with the survivors.

Witnesses, all of them experienced firefighters, said that this was no ordinary crown fire. To some it was a

Passage of the flame front was accompanied by a roaring sound, like that of a jet airplane ....

standing wall of flame that reached 200 feet above the treetops. Others described it as a huge rolling ball of fire with a bright orange glow. Some witnesses reported large balls of exploding gasses in the flame front.

Passage of the flame front was accompanied by a roaring sound, like that of a jet airplane or a train. One firefighter found this the most frightening part of the ordeal: "The noise builds up until you can't hear yourself think and then the ground begins to shake." He estimated that the shaking and roaring lasted 10 minutes. Over the roar of the fire he could hear the shouts of nearby firefighters screaming for reassurance, followed by shouts of encouragement from other firefighters.

Strong, fire-induced turbulence made it difficult to deploy shelters and keep them down. One witness reported a feeling of weightlessness, of being lifted off the ground. Another reported the shelter being slammed down against his legs. Within the safety zones, everyone moved as far as possible from the flame fronts by crawling along under the shelter.

Within the shelters, firefighters experienced extreme heat for as much as 10 minutes. Shelters were so hot that they could only be handled with gloves. Light entering the shelter through pinholes changed from dark red at peak intensity, to orange, to white, as the fire passed over. One survivor said that at one point the ground looked as though it had been painted a bright orange. Firefighters learned to evaluate the color of the light as an indication of the fire's intensity in order to judge when it was safe to come out of their shelters.

After leaving the shelters, some firefighters showed symptoms of carbon monoxide poisoning: vomiting, disorientation, difficulty in breathing. Emergency medical technicians administered oxygen to several individuals; five were evacuated to a hospital for treatment and observation. All fully recovered.

Among those interviewed, the consensus was that without the shelters none would have survived. A firefighter with 20 years' experience summed it up as follows: "The most frightening, scariest experience I've ever had. The fire was over us, around us, everywhere. I was in Vietnam for a year, but this beats it all."

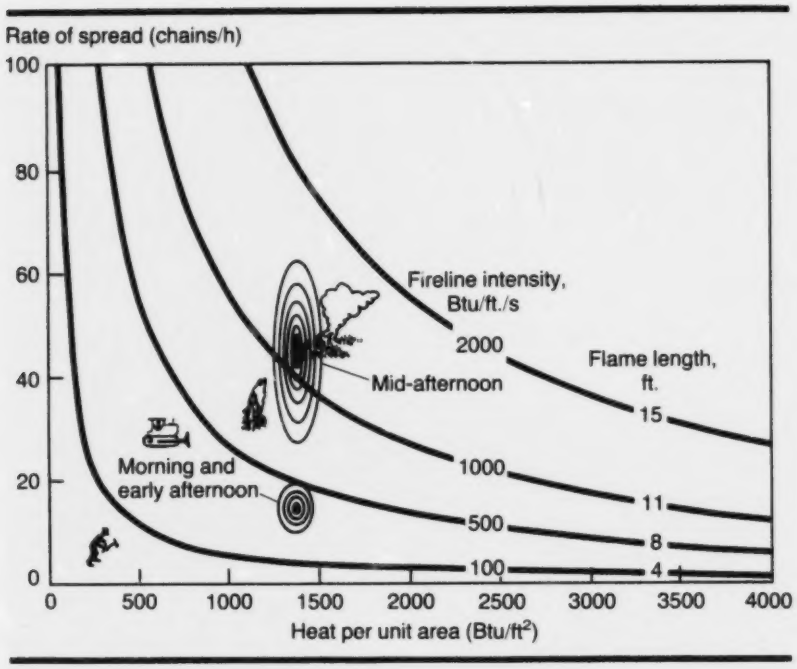
Factors Contributing to Fire Behavior

Fire activity in the preceding days contributed to the ease with which the fire in Wallace Creek began. Fire behavior on the afternoon of Thursday, August 29, was a repeat, albeit a much more severe repeat, of the fire behavior of the preceding two days. Each day took out more acreage and consequently left a larger holdover fire for the following day. On the morning of the 29th, the north edge of the fire was uncontained. Fuels were burned in patches, leaving large amounts of scorched fuel and trees within the fire area. The continuous fuels and lack of topographic barriers allowed the fire to move up the slopes of Wallace Creek with only moderate winds. The topography contributed substantially to the fire behavior and difficulty of control. The slopes from the valley bottoms were steep, contributing to rapid upslope runs; the ridge tops were rounded and covered with continuous fuels. Hence, there were no definite fire barriers such as steep rocky slopes, sharp ridges, or scrubby subalpine fuels.

Examination of weather records failed to reveal any factors that would have contributed to the large-scale convective activity observed on August 29. The extremely dry spring and summer probably contributed to the rapid spread of the fire and difficulty in controlling it. As on other fires in the northern Rocky Mountains at that time, tree crowns were extremely easy to ignite. Certainly the dry fuels on the ground also contributed, although the major fire runs at this elevation (6,000 to 8,000 feet) carried predominantly through the crowns.

Fire Behavior Analysis

Postfire analysis of the potential fire behavior in surface fuels was made with the BEHAVE fire prediction system *(1)* and displayed on the fire characteristics chart (fig. 4). Fuel model 10 was used. The values for fuel moistures ranged between 3 and 7 percent. The light winds of the



morning and early afternoon would have produced fireline intensities of 250 to 500 Btu/ft.sec, making the fire difficult to control. The stronger midafternoon winds would have produced fireline intensities in the surface fuels of 600 to 1,500 Btu/ft. sec, virtually assuring an uncontrollable crown fire. The range of the conditions is shown by the ellipses on the fire characteristics chart. The inputs to BEHAVE and the outputs produced are shown in table 2.

The calculated rate of spread in the surface fuels was 11 to 19 chains per hour in the morning and early afternoon. The higher windspeeds in midafternoon would have pushed the rate up to 28 to 57 chains per hour. We do not have methods for calculating crown fire rate of spread, but it has been found that crown fire spread can be 2 to 4 times faster than the rate of spread calculated for fuel model 10 in fuels exposed to the wind and as much as 8 times faster if the fire is going up steep slopes *(2)*. If we compare the calculated rate of spread in the surface fuels with the crown fire values given in table 2, we find that for the period 1430 to 1530 the crown fire was 1.4 to 2.3 times faster than the surface fire. In late afternoon, from 1530 to 1610, the crown fire was 2.6 to 5.3 times faster. These values fall within the suggested range mentioned above.

There is a great deal of uncertainty in this type of calculation, indicating a strong need for research on crown fire behavior and better guidelines for predicting the onset and spread of crown fires and potential blowup situations.

Conclusions

The type of fire run observed in upper Wallace Creek on August 29 was not unusual for fires in lodgepole pine during the 1985 fire season throughout the northern Rocky Mountains. The high-intensity fire runs were the result of drought-induced, extremely low fuel moistures in all size classes and the speed of the transition from surface fires to torching, spotting, and crowning fires. Because large areas were burning unchecked by either fireline or natural barriers and a southerly gradient wind had reinforced upslope and upcanyon afternoon winds in Wallace Creek, the direction of fire spread and crown fire development before 1530 were not a surprise. The distance the fire spread from 1530 to 1600, and its severity,

Table 2a—*Data used in BEHAVE to assess fire behavior in surface fuels on the Butte Fire*

Element	Data
Fuel model	10
1-hr fuel moisture	3 to 7%
10-hr fuel moisture	6%
100-hr fuel moisture	9%
Live woody moisture	75%
Midflame windspeed:	
Early afternoon (sheltered)	4 to 6 mi/h
Midafternoon (exposed)	10 to 15 mi/h
Percent slope	45%
Wind direction	Directly uphill

Table 2b—*BEHAVE outputs*

Time	Rate of spread	Heat per unit area	Fireline intensity	Flame length
	chains/hr	*Btu/ft²*	*Btu/ft.sec*	*ft*
Early afternoon	11–19	1286–1487	251–523	5.7–8
Midafternoon	28–57	1286–1487	664–1563	8.9–13.3

were, however, unexpected. The large area of holdover fire adjacent to continuous timber with heavy surface fuels proved to be a juxtaposition capable of generating an incredible amount of energy in a short time.

Although crown fires are often associated with strong winds, in this case winds of only 10 to 15 miles per hour, with some stronger gusts, were sufficiently strong to channel the flow up the canyon and produce the exceptionally intense crown fire that overran the crews. The question arose as to whether the burnout operation with the helitorch on the south side of the fire directly accelerated the high intensity run up Wallace Creek. Interviews combined with a careful inspection of burning patterns on a 1/24,000 aerial photo mosaic did not reveal any fire behavior process whereby the helitorch burnout could have accelerated the run up Wallace Creek. The photo mosaic showed a patchy pattern of burned and unburned areas between the helitorch burning at the confluence of Wallace and Owl Creeks and upper Wallace Creek. The burnout operation, however, probably contributed to the shelter incident by preoccupying the attention of some key overhead personnel for so much of the afternoon of August 29. The "eyes in the sky" reconnaissance that had been routinely available on previous days was not available during the critical time on August 29.

Early reports on the Butte Fire estimated that the fire traveled 2 miles up Wallace Creek in 15 minutes, or a spread rate of 8 miles per hour. This estimate now appears to be considerably higher than the actual rate of spread. Reconstruction of the fire front location at various times indicated that the average spread rate was closer to 2 miles per hour with a maximum of about 3½ miles per hour.

The safety zones that were bulldozed into the tractor line at the head of Wallace Creek made it possible for 73 firefighters to safely and effectively use their fire shelters and survive one of the more violent fire runs observed in the northern Rockies in 1985. But, as one crew foreman observed after the incident, "the best safety zone is one where a fire shelter is not needed." This conclusion deserves special emphasis whenever the Butte Fire is discussed.

Preventing Future Incidents

What measures can be taken to prevent such a life-threatening event from recurring in the future? If an indirect attack strategy is selected, then a fail-safe warning system must be in place to absolutely clear the line of personnel well in advance of a high-intensity run. Another approach in conifer forests is to select a direct attack strategy, build a line along the flanks of the fire from a well-secured anchor point, and attack the head of the fire only when fuels, weather, and topographic conditions allow firefighters to work safely.

Whatever the strategy selected, the fundamental principles of fire behavior and fire suppression should always guide decisions that affect the health and welfare of the firefighter. Despite the remarkable progress made in fire management in the past quarter of a century—better understanding of fire behavior, better trained and equipped fire crews, more flexibility in attack strategy—conditions like those experienced in the northern Rockies in the summer of 1985 call for extreme vigilance in all aspects of fire suppression. And the safety of the individual firefighter is always the top priority. ■

Literature Cited

1. Andrews, Patricia L. BEHAVE: Fire behavior prediction and fuel modeling system—BURN subsystem, Part 1. Gen. Tech. Rep. INT–194. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986. 130 p.
2. Rothermel, Richard C. How to predict the spread and intensity of forest and range fires. Gen. Tech. Rep. INT–143. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985.
3. U.S. Department of Agriculture, Forest Service. Your Fire Shelter. Missoula, MT: Missoula Equipment Development Center; 1984.
4. Van Wagner, C.E. Conditions for the start and spread of crown fire. Canadian Journal of Forest Research 7:23–24. 1977.

Butte Fire Shelter Videotape Available

A 33-minute videotape on the "Butte Fire Shelter Deployment" is now available from the Boise Interagency Fire Center. Videotaped onsite interviews with shelter occupants just days after the incident vividly demonstrate the importance of every firefighter having a shelter, knowing deployment procedures, and caring for the shelter properly. The videotape provides an excellent supplement to Missoula Equipment Development Center's new training film on fire shelters. Copies of the videotape can be ordered from:

Bureau of Land Management
Boise Interagency Fire Center
3905 Vista Ave.
Boise, ID 83705

The tape is offered in the following formats:

1. Order No. NFES 1523 3/4" U-matic $22.64
2. Order No. NFES 1524 1/2" VHS 11.24
3. Order No. NFES 1527 1/2" Beta 11.24

Add 19% to all orders for shipping and handling.

An Application of NIIMS on the Uinta National Forest

Helen Woods and Lyle Gomm

Program assistant and chief, Branch of Recreation and Lands, respectively, Uinta National Forest, Provo, UT

Since the implementation of the National Interagency Incident Management System (NIIMS), local offices of Federal agencies and State and local agencies, have banded together to cooperatively manage community emergencies such as fire, floods, toxic spills, aircraft disasters, rescues, earthquakes, and riots. One of the specific cooperative ventures, a pump and hose-lay team, is described in this article to show how agencies are working together more effectively and efficiently under NIIMS.

Many fires along the Wasatch Front of the Uinta National Forest occur in locations where they can be effectively suppressed using water from nearby lakes, streams, and irrigation canals or ditches. Most of these fires start in heavily used campgrounds and other recreation areas located in river and creek bottoms. The burning of ditchbanks on farms, debris burning, and other misuses of fire also contribute. In accordance with the NIIMS concept, the Uinta National Forest, the Bureau of Land Management, Utah Division of State Lands and Forestry, and Utah County have cooperatively organized a pump and hose-lay team to fight fires within their jurisdiction.

The pump and hose-lay team is a group of trained firefighters from the cooperating agencies who can effectively take advantage of available water sources to fight fires along the steep Wasatch Front and in areas that are often inaccessible to engines. This team is trained to work together dur-

Figure 1—*Cooperating agencies worked together to set up a pump and hose-lay team to help fight fires in the Uinta National Forest.*

Figure 2—*Equipment used by pump and hose-lay team.*

ing the initial stages of the incident to set up the system. After the hose system is in place, the crew can then split into two three-person shifts and utilize other, untrained personnel to work along with them. The crew is also trained in the use of gravity-fed systems that are used if the water source is high or if a helicopter is used to fill a tank on a ridge and the fire lies below in a canyon.

The pump and hose-lay team is designed to provide initial and secondary attack on frontal slope wildfires within and adjacent to Utah County. The high-risk and flashy fuels located along the Wasatch Front require immediate and aggressive action once a fire is identified. Any fire in this area has potential to be threatening to life and property.

A trailer to house the unit was constructed by the Forest Service and is capable of carrying pumps and hose equipment needed to run hose 3,000 feet horizontally and 1,000 feet vertically (fig. 1-2). There are three large pumps, two Mark III pumps, and one Chrysler Flotopump. To augment the large pumps, the two smaller Mark III pumps (contributed by the Utah Division of State Lands and Forestry) are used to run smaller lines from relay tanks set up to help in moving the water uphill. The exact pump configuration, of course, depends on the situation and application. Four lightweight relay tanks are included, along with a much larger 500-gallon, open-top tank suitable for helicopter fill operations. Much of the hose and necessary fittings have been contributed by the Bureau of Land Management. Utah County took care of painting the trailer. Utah County has also worked with the Forest Service in training part of its strike team to operate the equipment and use the trailer.

The equipment carried on the trailer is suitable for pumping operations, but it can also be used with city fire hydrants. It can be used in remote or desert areas with either large tankers

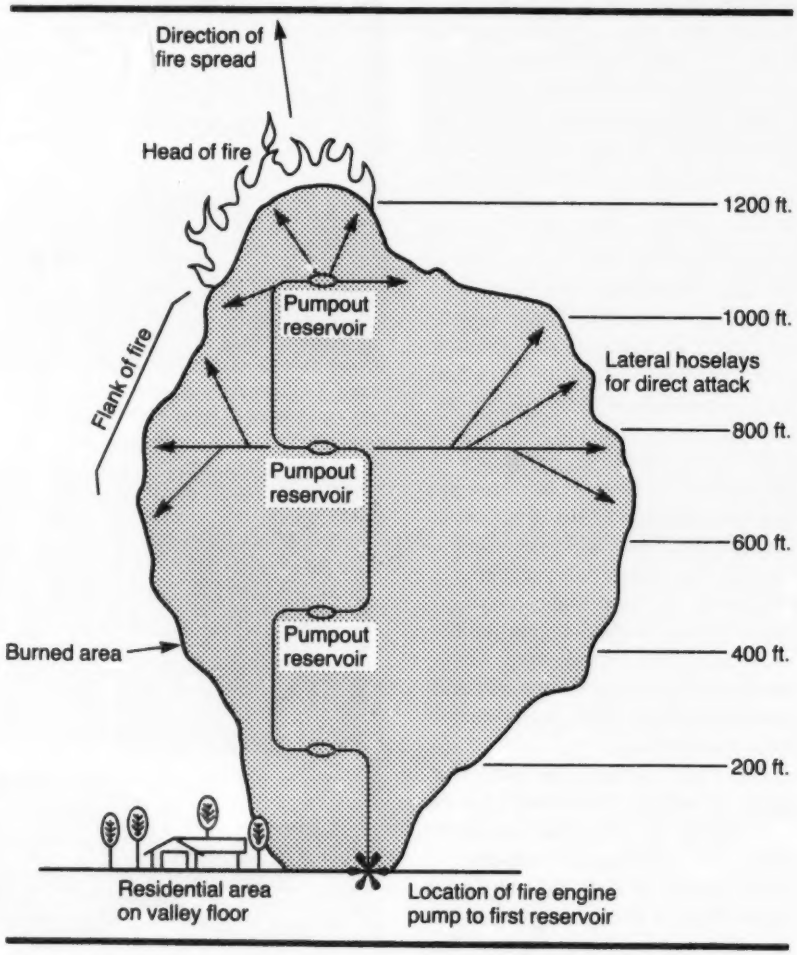


Figure 3—*Diagram of use of equipment to fight a typical frontal fire.*

or helicopter drops into artificial ponds. These alternative water sources would be more expensive than using a nearby lake or stream.

The equipment used by the team is designed to make water readily available up 1,000-foot vertical slopes. This is achieved through lightweight pumps, small reservoirs, and thousands of feet of linen hose. The equipment is designed to be backpacked up the slope as the fire develops. It is also designed for fighting the fire from within the burned area. In this way, direct attack can be made ahead of the fire without threat to firefighter safety (fig. 3-4).

Other pieces of equipment have been assembled, under the NIIMS concept, to supplement the hose-lay unit. The Interagency Incident Command Post trailer contains all necessary equipment for an efficient fire management operation. A military-type command and staff organization functions out of this trailer to handle incident objectives to which it is assigned (fig. 5).

During the fire season, the trailer is outfitted with a generator, lights, sleeping gear, and other personal gear for six crew members. The unit also contains radio equipment for communications to all cooperating agencies and functions as a backup unit to the central dispatch office located in the Utah County sheriff's office.

A personal computer will be housed within this facility to provide telecommunication and word processing capability. The computer will be used to store and retrieve the information necessary to manage a large fire organization, information on overhead personnel, fire crews, earth-moving equipment, aircraft, fire engines, and so forth.

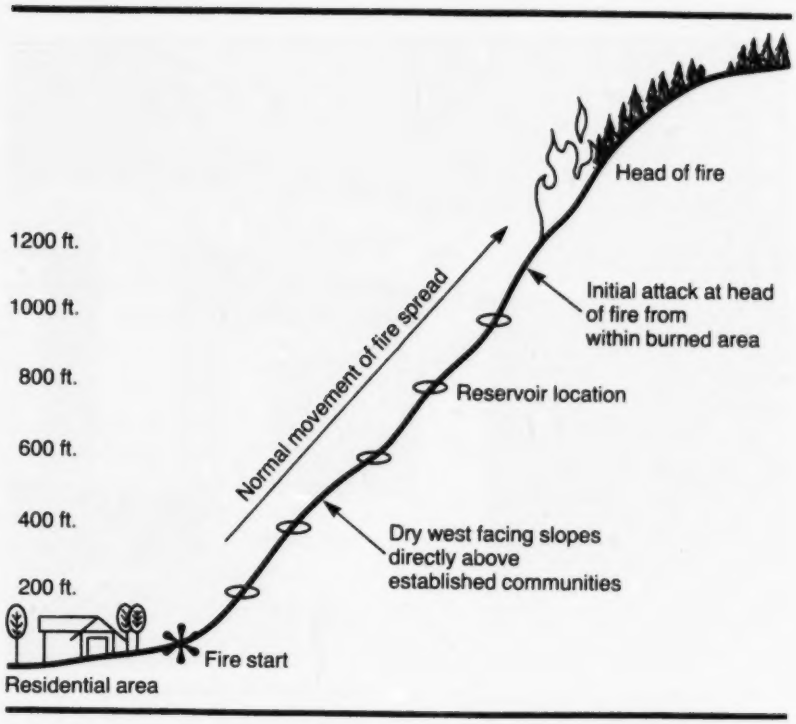


Figure 4—*Equipment used by the pump and hose-lay team is designed to make water available up 1,000-foot vertical slopes.*

In the Uinta National Forest, NIIMS is working and working well. The cooperating agencies are experiencing success in the joint management of fire and other community emergencies that may arise. The effective interagency cooperation shown in developing and maintaining the command post trailer and the pump and hose-lay team is evidence of the success, of the NIIMS concept.

Utah County firefighters are excited about the training they are receiving in fighting wildfires. Forest Service crews are eager to use the new equipment. Each contributing agency can see with pride the result of cooperation. ■

Figure 5—*Command post trailer organized under NIIMS concept contains equipment for efficient fire management operation.*

Current Status of BEHAVE System

Roger L. Eubanks, Roger L. Bradshaw, and Patricia L. Andrews

Fuels management specialist, USDA Forest Service, Washington, DC; computer programmer/analyst, USDA Forest Service, Boise, ID; and mathematician, USDA Forest Service, Missoula, MT

BEHAVE is a set of interactive, user-friendly computer programs that are used for site-specific fire behavior prediction. An overview of BEHAVE was given in a previous Fire Management Notes article by Richard C. Rothermel, "BEHAVE and YOU Can Predict Fire Behavior" *(5)*. That article included information on what BEHAVE can do, where BEHAVE applies, and how to make specific applications. This article will give information on the current status of the BEHAVE system, documentation that is available, how the programs can be accessed, and additional development that is underway.

Responsibility

BEHAVE was developed by USDA Forest Service Research personnel at the Intermountain Fire Sciences Laboratory (previously known as the Northern Forest Fire Laboratory). The Aviation and Fire Management Staff in the Forest Service Washington, DC, office has accepted BEHAVE as a national system. Local specialists trained in the BEHAVE system are responsible for providing users with assistance in operating BEHAVE. BEHAVE instructors have been trained in each Forest Service region and in other Federal agencies that have wildland fire management responsibilities. Others who have received training as instructors include State and university employees. This corps of instructors has responsibility for training additional BEHAVE users.

Documentation

The primary documentation of the BEHAVE system consists of two Forest Service Intermountain Station General Technical Reports (GTR). Burgan and Rothermel describe the FUEL subsystem *(3)*; Andrews describes the BURN subsystem *(1)*. Rothermel's GTR "How to Predict the Spread and Intensity of Forest and Range Fires" *(4)* provides the basis for his article "BEHAVE and YOU Can Predict Fire Behavior" *(5)* and Andrews and Burgan's "'BEHAVE' in the Wilderness!" *(2)*. The BEHAVE Terminal User's Guide is a quick reference for worksheets, codes, program structure, etc. It is printed in looseleaf format to allow for future updates.

The two GTR's and the Terminal User's Guide are available through the NWCG Publications Management System in Boise, ID.

Programs

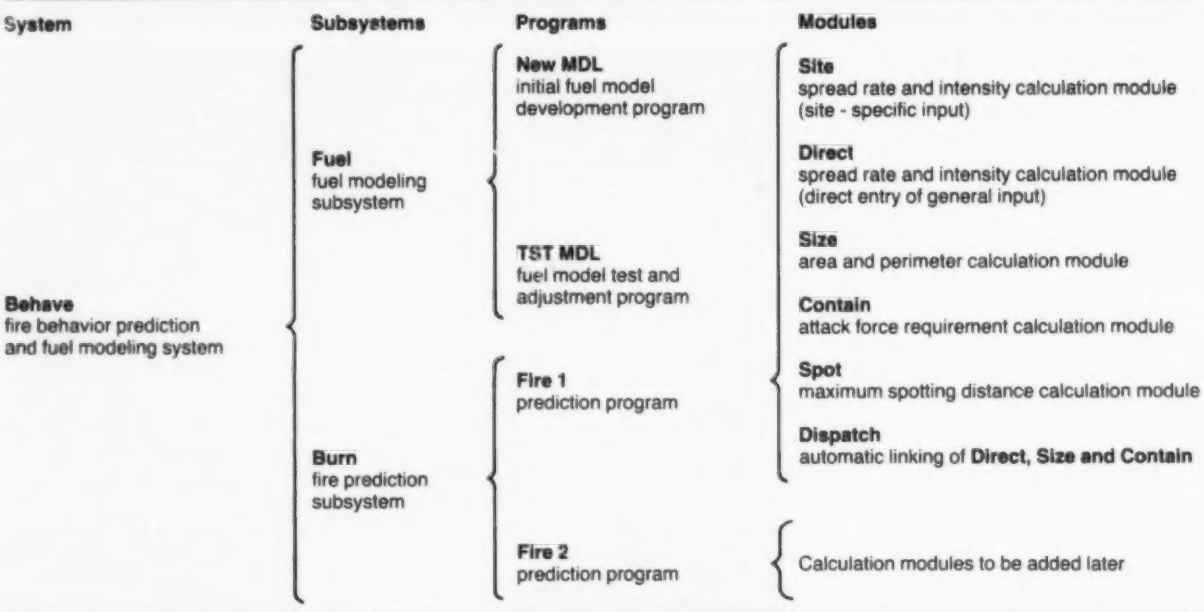
The master copy of the BEHAVE programs is maintained on the USDA computer in Ft. Collins, CO. The source code is available to users who wish to use BEHAVE on their own computers. The programs are written in ANSI Standard X3.9-1978 Fortran. The largest program, FIRE 1, requires approximately 260K bytes to load on Data General MV/8000. BEHAVE is being successfully used on a variety of computers.

Forest Service users with Data General equipment will receive the BEHAVE programs and all updates through the regular Forest Service software update procedures. The local systems manager is responsible for deciding whether or not to place BEHAVE on the system. Those not using Data General may send a written request to Roger Bradshaw stating their name, address, and phone number. Requests for tapes should include the character set, tape density, blocking, labeling, tracks, record length, and a blank tape.

Modification of the programs to run on a local computer is the responsibility of the user. Users are also responsible for making sure that any local copies of the program match the master. Version numbers are used to indicate changes made in one or more of the BEHAVE system programs. A change in the tenth's digit indicates minor changes that correct program errors or enhance existing features; the one's digit indicates major changes such as the addition of new prediction models. At the time of this writing the version number of all three programs is 3.3.

A BEHAVE conference is on the conference system at the Ft. Collins Computer Center. The conference will be used to announce new versions of the programs, indicate necessary changes, and tell how to obtain updates. Users are responsible for monitoring the conference or making other arrangements for obtaining announcements.

Requests from outside of the United States are handled by Patricia



Subsystems, programs, and modules that make up the BEHAVE fire behavior prediction and fuel modeling system.

L. Andrews. She will see that foreign users are kept informed of updates. An attempt will be made to arrange for a single contact for each country. So far, BEHAVE has been sent to Canada, Australia, South Africa, Spain, Mexico, and Portugal.

Updates

A diagram of the current BEHAVE system design is shown in figure 1. The FUEL subsystem consists of the programs NEWMDL and TSTMDL. At this time the BURN subsystem has only the FIRE 1 program. However, a FIRE 2 program is being developed, and the FIRE 1 program is being expanded. FIRE 2 will include the following modules:

- MOISTURE—The fine dead fuel moisture model that is now in SITE. This model will allow table output for ranges of input parameters as well as graphic output showing diurnal variation.
- IGNITE—Probability of ignition.
- RH—Relative humidity and dew point from elevation; wet bulb and dry bulb temperatures.

The FIRE 1 program will be expanded as follows:

- SPOT—Addition of spotting distance from wind-driven surface fires.
- CONTAIN—Addition of containment by indirect attack.
- SCORCH—Scorch height.

The keywords LOG and NOLOG are in the current version of BEHAVE, but they are not described in the formal documentation. This description was added in response to user request. Because the BEHAVE programs are interactive, printing an entire session on paper is quite unwieldy. The LOG option saves only input listings and computed results in a file. When the session is complete, the user is reminded to print the file and then delete it. (The method of printing and deleting is a function of the user's computer and is not part of the BEHAVE system.) In this way a user can use a nonprinting terminal,

yet have paper printout of the important parts of the run. The next version of the BURN programs will also have the keyword COMMENT to allow user notes to be printed in the file.

Summary

BEHAVE has been an approved national system since 1984 and is currently being used for a variety of fire management applications. It is a dynamic system that is expected to change as new technology becomes available for field application. Watch for future articles in Fire Management Notes describing the updates and applications in more detail.

If you have any questions or suggestions, contact Roger Eubanks at:

USDA Forest Service
P.O. Box 2417
Washington, DC 20013
(703) 235–8666
FTS 235–8666

Program maintenance is performed by Roger Bradshaw, who can be reached at:

USDA Forest Service
3905 Vista Ave.
Boise, ID 83705
(208) 334–9458
FTS 554–9458

Requests from outside the United States should be directed to Patricia L. Andrews at:

Intermountain Fire Sciences Laboratory
P.O. Box 8089
Missoula, MT 59807
(406) 329–4827
FTS 584–4827 ■

Literature Cited

1. Andrews, Patricia L. BEHAVE: Fire behavior prediction and fuel modeling system—BURN subsystem. Gen Tech. Rep. INT–194. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1986. 130 p.
2. Andrews, Patricia L.; Burgan, Robert E. "BEHAVE" in the wilderness! In: Lotan, James E.; Kilgore, Bruce M.; Fischer, William E.; Mutch, Robert W., tech. coords. Proceedings, symposium and workshop on wilderness fire; 1983 November 15–18; Missoula, MT. Gen. Tech. Rep. INT–182. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1985: 306–309.
3. Burgan, Robert E.; Rothermel, Richard C. BEHAVE: Fire behavior prediction and fuel modeling system—FUEL subsystem. Gen. Tech. Rep. INT–167. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 126 p.
4. Rothermel, Richard C. How to predict the spread of forest and range fires. Gen. Tech. Rep. INT–143. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983. 161 p.
5. Rothermel, Richard C. BEHAVE and YOU can predict fire behavior. Fire Management Notes. 44(4): 11–15; 1983.

Crew Mobilization: What's the Next Step?

Stephen W. Creech

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This is the second part of a two-part article dealing with interagency fire crew mobilization. Part 1 dealt with the preparation and planning that are necessary to pull personnel together in the most efficient manner to meet mobilization deadlines. Part 2 will deal with fire camp, fireline operations, and demobilization. This information is intended to address some of the problems that the crew boss/strike team leader, and squad boss, as well as, rookie and veteran firefighters, may encounter and to offer suggestions to make the assignment as positive an experience as possible. We must all remember that our role in these assignments is to serve the host agency and not vice versa.

Part I left off as the crew boarded the aircraft for the fire assignment. We will now pick up as the plane lands, and we begin our assignment. However, you and your crew have not already encountered lengthy delays you had better prepare yourselves for the inevitable. These sometimes lengthy and always frustrating delays are probably the number one enemy of good crew morale. Dealing with the possibility of delays at the beginning can prevent more serious problems later on.

What I would like to do now is deviate from the story line a bit to look at some of the National Interagency Fire Coordination Center (NIFCC) statistics for 1985. There were approximately 83,000 reported fire starts that burned more than 2,975,000 acres. To combat these fires required in excess of 25 class I teams, 2,510 miscellaneous overhead, 276 category I crews, 1,010 category II crews, 749 smokejumpers, 473 fixed and rotary wing aircraft (fire suppression aircraft), $9,721,000 worth of catering services, $1,194,000 worth of shower facilities, and $8,500,000 worth of charter and contract aircraft. In addition, more than 50,000 firefighters were moved throughout the country. These statistics do not include ground transportation or the assistance provided from the military.

I think that now you can appreciate a little better why there may be some unexpected delays and perhaps be able to deal more effectively with the questions fired at you from the crew. I will now jump ahead a bit and assume that we have safely reached fire camp.

Fire camp is always a very hectic place. Don't expect to be greeted at the gate and shown to your quarters. The first thing to do is to let someone know that your crew has arrived. The fire camp may be operated under either the National Interagency Incident Management System (NIIMS) or the Large Fire Organization (LFO). The reporting procedure will vary. Under NIIMS, the strike team leader/crew boss or the crew representative should first report to the planning section, resource unit leader (RESTAT). Under LFO the crew boss would report to the maps and records section.

You should understand that your crew members may be utilized in one of several ways. They may be considered a single resource, they may be joined with another crew and formed into a strike team, or they may become part of a task force. How they are utilized will depend upon the needs of the incident and may change according to changing needs.

Next, crew manifests and timesheets must be taken to the finance section (this is the same under both NIIMS and LFO). A close check should be made here to see that a timesheet is made out for each member of the crew. A little extra effort here can prevent problems later on. The last stop will be to check in with the staging area manager (NIIMS) or the camp officer (LFO). Here you will be assigned an area to assemble your crew. Once this area is established, place a sign (one may be provided) on the perimeter showing the crew name and crew leader. This area will become your home for the next several days.

The strike team leader/crew boss must decide if the crew is sufficiently rested, considering travel time and rest opportunities, to accept a line assignment. The incident may not require that your crew be placed on the fireline immediately, but if you are asked to assume a fireline role, it is your responsibility as leader to evaluate the crew's ability to safely carry out out the assignment. The crew's well-being depends on you. Regardless of whether you are immediately assigned to line duty, there are certain things that must be routinely taken

care of concerning your personnel.

Your crew will do a better job if they are happy and healthy. Prevention is the key to success. Let's look at some simple yet effective preventive measures:

1. **Hold briefings.** Your crew members want to know what is going on. They are not looking for detailed information—they just want to know what is happening and what is their role. Where are they? Where will they be going? What is the fire doing? What is the terrain like? How long is the work shift? Tell them what you know. Don't lie and don't speculate. Personnel who feel informed will have fewer morale problems than those who are kept in the dark.

2. **Information dissemination.** Make sure good information gets back to the home unit and that the home unit passes the information along to family and friends left behind. The good public relations that can be obtained from fire assignments goes a long way to ensure that the crew members will be available the next time they are needed. As long as the firefighting personnel feel that their best interest is being considered, they will remain happy and productive. It will be necessary to plan ahead how and when family and friends will be contacted. The home unit has the responsibility to disseminate timely information. Planning is the key to success here.

3. **Proper camp habits.** Insist on good eating, rest, and hygiene habits. Failure to adhere to any one of these can spell disaster. The need to observe this must be stressed at the early briefings. Individual counseling may be necessary in some cases. Since the fire situation can change very rapidly, it may be necessary to alter plans. For that reason it is suggested that a schedule be established while the crew is in camp, so that someone is at the designated crew area at all times. This will greatly improve response time and will eliminate unnecesary delays.

Note—As a strike team leader/crew boss you may be faced with a situation where your crew is allowed to go into a nearby town. This can happen during staging or during 24-hour on/24-hour off work cycles. You are still responsible for your personnel, and you have the ultimate authority to approve or deny the privilege. It is not an easy decision and can prove most unpopular.

4. **First aid.** First-aid problems must be attended to immediately. Problems can occur while on the line or in camp. Don't assume the problem will go away. Make sure prompt medical attention is provided. If first-aid is administered on the line, have the individual report to the first-aid facility upon return to camp. Document any problems to assist in future claims.

5. **Personal problems.** Action here must be swift and firm. You may need help in dealing with certain matters so don't be afraid to ask. Morale or attitude problems, if left unchecked, can rapidly spread to other personnel and literally disable a crew. All members of the crew should feel as though they can discuss their problems openly at any time.

6. **Safety.** Safety is one area that can never be stressed enough. Safety in camp, on the way to the fireline, and on the line must be constantly monitored. Unsafe conditions should be corrected or brought to the attention of others. Don't think that the Safety Officer can catch every safety problem. Safety is the responsibility of all firefighters, but particularly those in a supervisory position.

7. **Performance evaluation.** It is the crew member's responsibility to obtain crew performance evaluations from the unit supervisors they are working for. Don't assume that the evaluations will automatically be completed for you. The crew performance evaluation is proof of how well your crew performed and should point out areas that need improvement. These evaluations can mean the difference between being utilized properly and not being utilized at all. Incident commanders are looking for personnel who can do the job. The evaluation is your proof that you and your crew can perform satisfactorily.

The key to success on any fire assignment is to maintain control and work as a team (fig. 1). Work to the best of your ability, and don't be afraid to admit that you can't do something or that you are not properly trained or qualified. Firefighting is a dangerous profession and the more we all know and the more we work to-

Figure 1—*The fire crew's performance will be reflected in a crew performance evaluation.*

gether the safer and more effective we become.

We will now assume that our assignment is completed and we have gone to demobilization status. Once you have fulfilled your time requirement or the emergency has subsided, you must be released back to your home unit. The process of checking out is much the same as checking in. You will be required to turn in any accountable, issued gear. You will have to verify, sign, and take charge of timesheets. You must obtain copies of any request for treatment forms from the first-aid area. Your camp area must be cleaned up, and you must sign out through RESTAT. It may seem harder to get out of camp than it did to get in.

Once you are sure of your demobilization plans, particularly flight plans, it is a good idea to make one last contact with your home unit to assure that someone will be there to meet you. Remember that on a large-scale operation things can change and messages and arrangements occasionally get messed up. It may not always be possible, but a short call just prior to demobilization may save a lot of confusion later on. You need to indicate mode of transportation, the carrier's name, the destination (airport and gate location if known), and approximate time of arrival. You might also plan to have a meal waiting just in case. This kind of planning isn't foolproof, but it sure helps smooth out the process.

Once you arrive at your official duty station, you still have a few loose ends to tie up before you can close the books on this incident. You need to reclaim the fire gear from your personnel. Any materials that came from the fire cache should be put back, or plans should be made to replenish depleted items. If it is feasible, have the crew members acknowledge that they arrived home safely. A quick phone call back to the home office or to the strike team leader/crew boss is all it takes.

You should plan to hold an assignment critique when time allows, preferably while the incident is still fresh in everyone's mind. The critique should look at the following areas:

1. **Incident management.** You should include an evaluation of each of the phases of the assignment. Examine mobilization, staging, fire camp, line assignment, safety, organization, and demobilization. You are looking for items, both good and bad, that could make future assignments operate more efficiently.

2. **Personnel evaluation.** You need to look at all of your fire personnel and evaluate their performance on the assignment. Did they follow orders? Were they team players? Were they good representatives of your home unit? Did they perform up to standard? Could they be considered for transfer to a different position (for example, firefighter to squad boss, or

squad boss to strike team leader/crew boss)? Were they physically qualified? Poor performers should be removed from the roster and not allowed to participate in future assignments until shortcomings are rectified. Remember the whole team's evaluation may hinge on one person's actions.

3. **Training needs.** You should evaluate training needs very closely. Was there a need for training that you or your crew have not had? Do certain personnel need a refresher course? Is there a need for more advanced training for some of your personnel? Training is an ongoing consideration. It is needed both to maintain proficiency and to prepare personnel for advancement.

Once you have completed the critique you should make copies available to your home office, the sending agency, the receiving agency, and each of your personnel. The critique should be objective and honest. You should immediately develop a plan of action to correct those areas within your jurisdiction that need improvement. Your efforts here will pay off on the next assignment for everyone.

If you are a veteran leader you should have picked up some helpful reminders from this article. If you are a veteran firefighter you should have gained some useful information in case you are ever given the responsibility to lead your own crew/strike team. If you have only dreamed of going on an out-of-state fire assignment you should have a better appreciation of what to expect and also a better understanding of what goes into such a complex undertaking. ■

Late-Winter Prescribed Burns to Prepare Seedbeds for Natural Loblolly–Shortleaf Pine Regeneration—Are They Prudent?

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Density, percent stocking, and total heights of first-year loblolly and shortleaf pine (Pinus taeda *L. and* P. echinata *Mill.) seedlings were measured one growing season after a late-winter prescribed burn in uneven-aged pine stands in southern Arkansas. These data were compared with data from the same year for an area where there had been no prescribed burning. Although a partial seed catch on the late-winter burn area produced significantly fewer pine seedlings, the burn coincided with a bumper seed year that resulted in a high-density, well-stocked crop of pine seedlings after one growing season.*

Introduction

The use of prescribed fire for seedbed preparation in natural regeneration of loblolly and shortleaf pine (*Pinus taeda* L. and *P. echinata* Mill.) is widely practiced throughout the South. The recommended technique is to use a winter burn to reduce fuel accumulation and follow up with one or more hot summer burns to top-kill small hardwoods and expose mineral soil *(7)*. To maximize seed catch, prescribed burning should be done just before seedfall (*8, 16*). Such timing of prescribed burns will provide a mineral soil seedbed yet will not destroy the current year's seedfall.

Natural seedfall for loblolly pine begins in October and may persist into spring. However, seedfall monitoring in North Carolina has shown that 71 percent of loblolly seeds fall by the end of November *(1)* and that 84 percent of all loblolly seeds fall before January (*13*). Similarly, in south Arkansas, Grano (*12*) found loblolly-shortleaf pine seedfall to be 77 percent complete by the end of November and 92 percent complete by the end of December. Chaiken (*6*) monitored loblolly pine seedfall for 6 years in South Carolina and noted that 92 to 100 percent of all viable seeds were disseminated by February 1.

On the basis of these findings, an effort should be made to coordinate the timing of prescribed fires for seedbed preparation with natural pine seedfall. For example, Lotti and others (*14*) surmised that if a preharvest prescribed winter fire takes place after the main seedfall in loblolly pine stands, almost full dependence must be placed on the following years' seed crop for pine regeneration. The reasoning has been that pine seed on the ground will be destroyed by the fire.

Yet, fuel and weather conditions for prescribed burning in the South are often most favorable during the winter when cold weather fronts pass through with steady north winds *(8)*. It is therefore appropriate to investigate the effect of a late-winter prescribed burn on subsequent pine seedling establishment from a current year's seed crop.

Methods

Data for this investigation were obtained from two active research studies on the Crossett Experimental Forest in south Arkansas. Soil on the study areas is Bude silt loam (Glossaquic Fragiudalfs) with a site index of 85 to 90 feet for loblolly pine at age 50 years.

Study A—The purpose of this study was to assess the effects of prelogging hardwood control for establishment of natural pine regeneration. When the study began, the stand contained about 100 square feet of pine basal area per acre. On four 0.25-acre plots all hardwoods having a groundline diameter of 1 inch or larger were stem-injected with picloram (Tordon 101R) in March 1983. Herbicide spotguns were used to treat four other 0.25-acre plots with hexazinone (Velpar-L) using 4 pounds a.i. per acre on a 4- by 4-foot grid in April 1983. A basal area reduction harvest of overstory pines was done in July and August 1983, removing an average of 6,000 board feet per acre (International ¼-inch rule). This reduction left a 76-year-old even-aged stand of loblolly–shortleaf pines averaging 68 square feet of basal area per acre in 28 trees per acre. Since the intent of the study was to facilitate pine regeneration from natural seedfall, data from the study were used as a standard for comparison with data taken from the area where late-winter prescribed burning was done in study B.

Study B—The purpose of this study was to determine the effect of overstory pine basal area and cyclical

burning intervals on establishment and growth of pine regeneration in uneven-aged stands of loblolly–shortleaf pine. Before the study, these stands contained over 100 square feet of pine basal area per acre. Prescribed winter burns were first conducted on January 14 and 15, 1981. In August and September 1981, all hardwoods 1 inch in diameter at breast height (d.b.h.) and larger were stem injected with Tordon 101R. Merchantable pines were cut in June and July 1982, removing an average of 7,000 board feet per acre (International ¼-inch rule). This left a balanced uneven-aged structure with specified basal area averaging 72 square feet per acre in 110 trees per acre. Plots remained undisturbed after the 1982 harvest until January 31, 1984, when a second prescribed burn was conducted (table 1). Pine seedling establishment following the second late-winter burn is the subject of this investigation. Seedling data were taken within 2.5-acre gross plots where residual basal area averaged 78 square feet per acre in the fall of 1984.

An estimate of pine seed production was obtained from 40 seed collection traps (1/20 milacre each). These traps were on all 16 plots in study A and on 24 plots at 5 other locations in uneven-aged pine stands on the Crossett Experimental Forest. Seed counts were taken once a week from October 1983 through February 1984 (22 weeks). All collected pine seeds were cut open, and those containing fully grown, firm, undamaged tissue were judged as potentially viable *(3)*.

Table 1—*Average conditions during prescribed burning on January 31, 1984*

Variable	Measurement
Precipitation:	
Time since last accumulation	8 days
Amount	1.22 inches
Air temperature during burn	34 to 50 ° F
Relative humidity during burn	70 to 24 percent
Wind:	
Direction	From the south
Velocity	3 miles per hour
Time of day	10 am to 4 pm CST
Type of burn	Back and flank fires
Fine fuel moisture[1]	12 percent
Mean fireline intensity[2]	92 Btu/ft•sec
Range in fireline intensity	47 to 127 Btu/ft•sec
Estimated ground coverage by fire	83 percent

[1]Determined from fuel-moisture sticks at midday.
[2]Fireline intensity (I) *(5)* was calculated from over 100 ocular estimates of flame length (L_f), in feet, observed during the prescribed burns: $I = 5.67\ L_f^{2.27}$

In October and November of 1984, pine seedling counts were made one growing season after seedling establishment in both study A and study B. Nine 0.3-milacre circular quadrats were systematically established within the interior 0.1 acre on each of eight 0.25-acre gross plots in study A and on each of six 2.5-acre gross plots in study B. The number of pine seedling within each quadrat was counted and total height of every fifth seedling was measured to the nearest 0.1 foot. Although older pine seedlings could have been found on plots in study B, only first-year pine seedlings were encountered. The prescribed burn in January 1984 had apparently eliminated all previously established pine seedlings.

A *t*-test for unpaired plots between study A (8 plots) and study B (6 plots) was used for comparing mean density, percent stocking, and total height of first-year pine seedlings, as well as overstory pine basal area. All statistical tests were conducted at the 0.05 level of significance. Arc sine transformation was used in analysis of percent stocking.

Seed Crop

Total cumulative pine seedfall between October 1, 1983, and March 1, 1984, averaged over 1,170,000 seeds per acre with 81 percent considered sound. According to Baker and Balmer *(2)*, a good seed crop for loblolly pine is more than 80,000 sound seeds per acre, and an average crop is between 30,000 and 80,000 sound seeds per acre. Judging by these standards, the 1983–84 seedfall was a bumper crop. Based on the 22-week

collection period, pine seedfall was more than 75 percent complete by December 1 and 90 percent complete by the time of the January 31 prescribed burn.

Even though seedfall was nearly complete before burning in study B, the bumper seed year provided sufficient seeds after burning for ensuring natural pine regeneration. Ten percent of the sound seed crop, or nearly 95,000 sound seeds per acre, was collected in traps after January 31. Thus, in this bumper seed year, 10 percent of the crop was equal to an entire seed crop in an average seed year. Also, some additional seeding probably occurred after the March 1 termination date for seed collection.

Table 2—*Comparison of pine seedling establishment on seedbeds prepared before seedfall (A) and on seedbeds prepared after the bulk of seed had fallen (B)*

Seedbed treatment[1]	First-year pine seedlings			1984 merchantable pine basal area
	Density	Stocking	Total height	
	Stems/acre	*Percent*	*Feet*	*Square feet/acre*
A	62,979 a[2]	100 a	0.46 a	70 a
B	20,607 b	89 b	0.36 b	78 b[3]

[1]A = Hardwood control + logging; B = Late-winter burn.
[2]Columnar means followed by the same letter are not significantly different at the 0.05 level.
[3]Estimated from 1982 postharvest inventory *(9)*.

Seedling Establishment

As would be expected, study area A, which had been site prepared for natural pine seeding prior to seedfall, had substantially more pine seedlings after 1 year when compared with study area B, which had received only partial seeding following the late-winter prescribed burn. First-year seedling density in study A, where there was a complete seed catch in the winter of 1983–84, averaged nearly 63,000 seedlings per acre. This figure was significantly higher than the nearly 21,000 seedlings per acre in study B with the partial seed catch (table 2). Stocking of first-year pine seedlings in study A averaged 100 percent, again significantly higher than the 89 percent stocking in study B (table 2).

Total height of first-year seedlings in study A averaged 0.46 feet, significantly taller than the first-year seedlings of study B, which averaged 0.36 feet (table 2). The additional 8 square feet of basal area in the overstory pines and higher stem density of merchantable pines in study B resulted in more shade and subsequently less growth of pine seedlings. Brender and Barber *(4)* reported that the level of pine overwood shade, measured by the height to live crown, ranks with overwood density as a major factor affecting the growth rate of loblolly pine seedlings and that survival and growth of understory pine seedlings are poorest under low overwood shade. Crown heights of the old-growth overwood in study A were taller than those of the uneven-aged overwood in study B.

Appreciably fewer pine seeds were required to produce a seedling in study B (5 seeds per seedling) compared to study A (15 seeds per seedling). Seeds that lay on the ground from early October until germination the following spring were available to any number of predators such as insects, birds, and woodlot mammals. Pine seeds that fell to the ground following the late-winter burn were available to predators for a much shorter period of time before spring germination. There are two possible sources of pine seedlings that arise on burned areas when burning is done after the bulk of seed has fallen. According to Chaiken *(6)*, either new seeds are disseminated after the fire or seeds that had lodged in sheltered or protected areas on the ground where they were not destroyed by fire were still viable.

Density and Stocking Recommendations

In uneven-aged management of loblolly-shortleaf pine, the recommended density for the submerchantable stand (≤4-inch d.b.h. classes) is 500 to 700 pines per acre *(10)*. On

clear-cut areas in even-aged management, it is desirable to have between 1,500 and 2,500 loblolly-shortleaf seedlings per acre the first year after establishment from natural seedfall *(11)*. Percent stocking is another criterion for judging the success or failure of natural pine regeneration. According to Trousdell *(15)*, areas that contain 90 percent stocking of loblolly pine seedlings from natural seedfall are considered well stocked.

In the investigation, after the late-winter prescribed burns in uneven-aged stands of loblolly-shortleaf pines during a bumper seed year, sufficient seeds were available to result in a high-density, well-stocked crop of pine seedlings. Although exact periodicity of bumper seed crops cannot be predicted, better than average or abundant seed crops of loblolly pine can occur at 2- to 4-year intervals *(13, 17)*.

Summary

When managing for natural loblolly-shortleaf pine regeneration using seed tree, shelterwood, or selection (uneven-aged) cutting methods, timing of seedbed preparation can be a critical consideration. Late-winter prescribed burning for seedbed preparation may result in an insufficient supply of viable seeds for regeneration purposes if done in poor to average seed years. For example, in this investigation, percent stocking and density of loblolly-shortleaf pine seedlings established following a late-winter prescribed burn were significantly less than stocking and density of seedlings on areas undisturbed during seedfall. Even so, a bumper pine seed crop that coincided with the late-winter burn resulted in a pine seedling stand that met or exceeded published recommendations for both adequate stocking and density.

These data suggest that land managers who rely on prescribed burning to prepare seedbeds in advance of natural pine seeding in the South can possibly extend the burning season through January during bumper seed years and still obtain adequate pine seed catch for regeneration purposes. ■

Literature Cited

1. Allen, Peter H.; Trousdell, Kenneth B. Loblolly pine seed production in the Virginia-North Carolina coastal plain. Journal of Forestry. 59: 187–190; 1961.
2. Baker, James B.; Balmer, William E. Loblolly pine. In: Silvicultural systems for the major forest types of the United States. Agric. Handb. 445. Washington, DC: U.S. Department of Agriculture; 1983: 148-152.
3. Bonner, F.T. Seed testing. In: Seeds of woody plants in the United States. Agric. Handb. 450. Washington, DC: U.S. Department of Agriculture; 1974: 136–152.
4. Brender, E.V.; Barber, John C. Influence of loblolly pine overwood on advance reproduction. Sta. Pap. 62. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 1956. 12 p.
5. Byram, George M. Combustion of forest fuels. In: Davis, Kenneth P., ed. Forest fire—control and use. New York: McGraw-Hill Book Co.; 1959: 61–89.
6. Chaiken, L.E. Extent of loss of loblolly pine seed in winter fires. Res. Note 21. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 1952. 2 p.
7. Crow, A. Bigler; Shilling, Charles L. Use of prescribed burning to enhance southern pine timber production. Southern Journal of Applied Forestry. 4(1): 15–18; 1980.
8. Davis, Kenneth P., ed. Forest fire—control and use. New York: McGraw-Hill Book Co.; 1959. 584 p.
9. Farrar, Robert M., Jr. Density control—natural stands. In: Karr, Bob L.; Baker, James B.; Monaghan, Tom, eds. Proceedings of the symposium on the loblolly pine ecosystem (west region); 1984 March 20–22; Jackson, MS. Mississippi State, MS: Mississippi Cooperative Extension Service; 1984: 129–154.
10. Farrar, Robert M., Jr.; Murphy, Paul A.; Willett, R. Larry. Tables for estimating growth and yield of uneven-aged stands of loblolly-shortleaf pine on average sites in the west gulf area. Bull. 874. Fayetteville, AR: Division of Agriculture, University of Arkansas, Arkansas Agricultural Experiment Station; 1984. 21 p.
11. Grano, Charles X. Growing loblolly and shortleaf pine in the midsouth. Farm. Bull. 2102. Washington, DC: U.S. Department of Agriculture; 1967. 27 p.
12. Grano, Charles X. Conditioning loessial soils for natural loblolly and shortleaf pine seeding. Res. Note SO-116. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1971. 4 p.
13. Jemison, George M.; Korstian, C.F. Loblolly pine seed production and dispersal. Journal of Forestry. 42: 734–741; 1944.
14. Lotti, Thomas; Klawitter, Ralph A.; LeGrande, W.P. Prescribed burning for understory control in loblolly pine stands of the Coastal Plain. Sta. Pap. 116. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 1960. 19 p.
15. Trousdell, Kenneth B. Favorable seedbed conditions for loblolly pine disappear 3 years after logging. Journal of Forestry. 52: 174-176; 1954.
16. Van Lear, David H. Natural regeneration of southern pines. In: Mann, John W., ed. Proceedings of a seminar on site preparation and regeneration management; 1980 November 18–20; Long Beach, MS. Long Beach, MS: Forestry and Harvesting Training Center and Clemson University; 1980: 64–72.
17. Wahlenberg, W.G. Loblolly pine: its use, ecology, regeneration, protection, growth, and management. Durham, NC: Duke University School of Forestry; 1960. 603 p.

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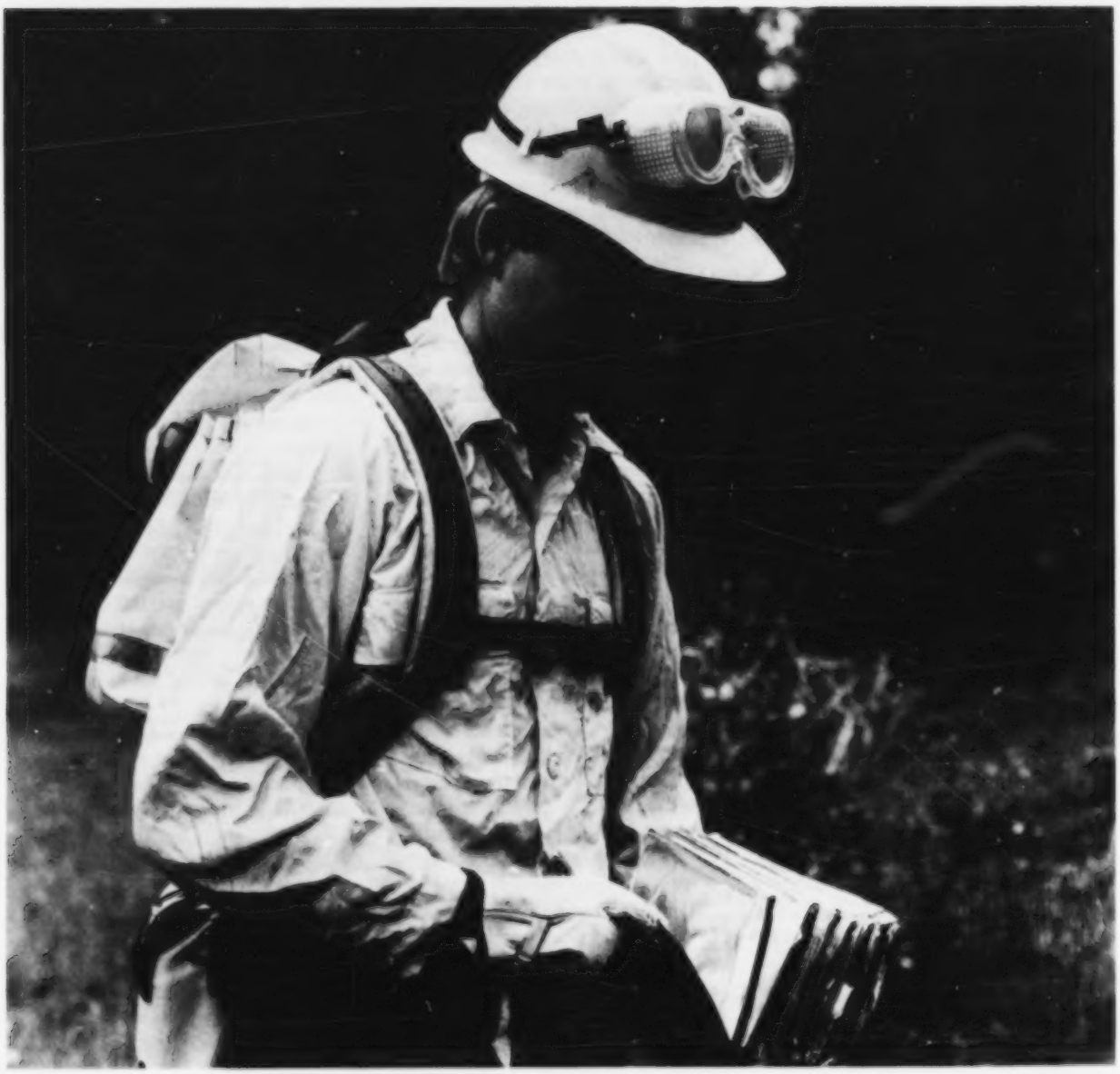

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Danger Zone: The Wildland/Urban Interface

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In October 1871, a fire in Peshtigo, WI, killed more than 1,500 people and burned 1.2 million acres. The Peshtigo Fire occurred in the same month as the infamous Chicago Fire. But while everyone has heard of Mrs. O'Leary's cow, few have heard of the Peshtigo fire in which four times as many people died.

Ancient history? Not so!

The 1985 wildland fire season was the most severe of this century. By the end of the fiscal year, over 83,000 wildfires had burned almost 3 million acres, destroyed or damaged in excess of 1,400 structures and dwellings, caused the deaths of 44 civilians and firefighters, and cost the Federal, State, and local fire agencies and private industry over 400 million dollars in firefighting costs. Damage estimates to natural resources and property are not available, but probably run into the hundreds of millions of dollars.

The Southern States east of the Appalachian Mountains from Florida to Virginia, parts of New England, Idaho, Nevada, and central California were especially hard hit by wildfires. National mobilization was needed in the Western States and in the South to cope with wildfires. During the first week of July, a total fire mobilization of over 20,000 Federal and State firefighters was committed to fires in 13 Western States, including massive fires in California, Idaho, Oregon, and Nevada.

The loss of property was the worst since 1871 when the Peshtigo Fire destroyed entire communities. Major losses of buildings occurred in Florida, North Carolina, and California, but reports of structure losses have also come from Washington, South Carolina, Oregon, and New England. The number of structures saved by wildland firefighters is not known, but wildfire reports routinely listed "structures threatened" in daily status reports. Because protection of property and lives took priority, natural resource losses increased when fire forces were diverted to protect structures.

Last year's loss in lives and property is part of a developing trend. A major population shift from urban to suburban living in the years since World War II has greatly expanded what is now called the urban/wildland or woodland home environment—the zone where people are in contact with the wildlands for reasons not related to timber or other traditional forest uses. Although this trend has increased the general population's appreciation for the amenity values of forests, it has also greatly increased the number of primary residences, second homes, and retirement homes located in forests and brushlands. Vast areas of the United States contain high-value properties intermingled with flammable native vegetation.

Structural fire losses are increasing dramatically as more people build and live in proximity to flammable plant communities. Major loss of life is possible—in fact, inevitable. The problem is not, as is often believed, one unique to southern California. The extension of residential and commercial development into areas with high fire risk has been noted throughout the Nation—from the Georgia Piedmont and the sand plains of central Michigan to the Rocky Mountain foothills near Denver to northern New England.

Although current fire management practices make it unlikely that fires will ever again reach the huge proportions of those in 19th-century America, the risks to life, property, natural resources, and economic welfare are much higher today then ever before. Huge fires are not required for catastrophic losses in the modern wildland/urban interface. Even small fires can be killers—three homeowners died when an 8-acre fire swept their Baldwin Hills, CA. subdivision. Fire management must change in order to better prevent and suppress smaller, fast-moving single and multiple fires as a wildland/urban interface continues to expand. This change must occur nationally.

The task of protecting lives and property from wildfires in the wildland/urban interface poses one of the most critical and elusive prob-

Most forest fire suppression personnel are inadequately prepared for fighting structural fires....

Losses of property and life as a result of fires in the wildland/urban interface have been increasing dramatically in recent years.

lems faced by wildfire protection agencies. Wildfire protection agencies have broken the problem down into several parts:

- Fire managers are unable to reliably predict erratic fire behavior in mixture of structures, ornamental vegetation, and wildland fuels characterizing the interface. Physical fuel properties and moisture relations in these areas are not well understood, as they are governed by both natural and human-caused phenomena. Possible relationships among building and landscaping location, design, and construction, with respect to terrain and other structures, add to the complexity of fire behavior. For example, spotting (fires starting from flying embers) is especially difficult to forecast due to the diversity of firebrand materials and unusually complex windflow patterns. Yet, spotting is the chief cause of structural fire ignitions in wildland/urban areas.
- Use of prescribed fire for hazard reduction (fires purposely set to remove undesirable vegetation) is made difficult by legal, political, and environmental concerns. Liability for damages to intermingled private holdings is a significant deterrent. In many cases, the very reason for living in the interface precludes the use of fire. Nonetheless, means must be found to manage fire hazards in the interface, while maintaining or enhancing desired environmental and economic values.
- Many property owners are unaware of the wildfire threat, and fire safety ordinances and building codes are frequently inadequate, unenforced, or disregarded. A quintessential example is the insistence on flammable roof materials in the chaparral area of southern California, but similar attitudes are exhibited throughout the world. The design of subdivisions, also, continues to defy principles of fire safety. Many areas include narrow, winding, or dead-end roads with inadequate water systems. Lots are frequently too narrow to permit effective vegetation removal. Without strong motivation to change, homeowners and developers will continue to produce and maintain these dangerous communities.
- Most forest fire suppression personnel are inadequately prepared for fighting structural fires, whereas municipal fire departments are not always fully trained or equipped for wildland fire suppression. Although relatively new organizational systems for integrating a variety of fire protection resources and personnel have proven effective, the special demands of fires in the wildland/urban interface often force firefighting personnel to perform unfa miliar tasks. The need to meld structural and vegetation fire expertise on interface fires remains a formidable challenge.

The following actions and improvements are needed:

- Effective techniques and strategies to assess and manage fire hazards in the wildland/urban interface.
- Aids for planning, budgeting, and training for increased involvement in the residential/wildland interface to ensure a balanced capability in conducting structural and wildland fire suppression activities.
- Effective ways to educate property owners, land developers, insurance carriers, and local planners about vegetation fire problems and solutions.
- Fundamental knowledge about the physics of fire spotting and crowning in the wildland/urban interface.
- Knowledge about relationships of building design, materials, and landscaping with fire hazard and behavior.
- Improved understanding of why people build fire-prone homes in highly some flammable areas and how they respond to various motivational tactics to reduce vulnerability.

Who is responsible for the solution, the fire protection agency, the homeowner, the county planner? The responsibility for fire protection cannot be relegated to a single element of society. It calls for a combined effort. Just a few of the groups that share in the responsibility include:

- Homeowners
- Fire protection agencies
- Local and regional planners
- Media and communication experts
- Insurance carriers
- Builders, contractors, and architects
- Training and motivational experts

A truly integrated approach to the problem would greatly reduce its impact. We all must take a hand in solving the problem. We must strive to avoid a 20th-century Peshtigo fire. There is no justification for continuation of such a serious hazard to life and property. ■

Chilean Fire Course

Ken Dittmer

Director, National Advanced Resource Technology Center, Marana, AZ

For the third time in as many years, firefighters from Central and South America, Spain, and Portugal gathered for training in various aspects of fire suppression. The most recent session, in late November and early December, 1985, was held near Santiago, Chile, rather than at the National Advanced Resource Technology Center (NARTC), Marana, AZ, where the two previous courses had been held. Through the combined efforts of 17 fire experts from Spain, Argentina, Chile, and the United States, 56 firemen representing 15 countries were trained in the latest techniques and philosophies of fire suppression. It is hoped that these individuals will be able to train others upon returning home.

During the 2 weeks of classroom training, the students were given courses in effective training techniques, fire behavior, prevention and detection, fuels management, organization for suppression, line construction, and air operations. A week of field exercises in early December, the start of the fire season south of the equator, afforded the students an opportunity to apply what had been presented in the classroom and to participate in a prescribed burn. Field trips to national and private fire facilities and forest operations exposed the trainees to a fine example of organization and cooperation in an environment similar to what they are accustomed to at home.

Smokey Bear and his Chilean counterpart, Forestin the beaver, share the fire prevention message with Chilean schoolchildren.

Funding for Tercer Curso International Avanzado, El Combate de Incendios Forestales was made available through the Agency for International Development (AID); Coorpracion Nacional Forestales (CONAF), the national land managing agency of Chile; and the U.S. Department of Agriculture Forest Service.

Smokey Bear made his first trip outside the United States, joining his Chilean counterpart, Forestin, a beaver, in promoting fire prevention. Smokey and Forestin visited several schools to pass out fire prevention material and appeared on national television.

As part of the continuing effort to attempt to share experience and technology among countries, Mexico plans to host a similar course in 1987. ■

Florida NIIMS Resource Inventory Program

J.P. Greene and James Brenner

Fire management specialist and fire prevention coordinator, respectively, Florida Division of Forestry, Tallahassee, FL

When the Florida National Interagency Incident Management System (NIIMS) Task Force was formed in 1982, one of its first actions was to form a logistics working team with the mission of developing a workable wildland fire suppression and support resources inventory for the State.

In order to inventory resources, it is first necessary to define the resources in such a manner as to ensure that the inventory is uniform and accurate. When considering fire suppression resources, however, enough flexibility must be built into the system to allow for variations in equipment while ensuring that the resource will do the job desired. Using the southern California definitions as a model, the team generated a list of resources adapted to the Southeast in general and Florida in particular. As outlined in national doctrine, resources are typed by capability, with lower numbers having generally greater capabilities.

After adoption of the resource definitions, an inventory method was devised. An inventory form was developed and distributed to the 17 Florida Division of Forestry districts for completion. Fire departments, forest industry cooperators, and Federal, State, and local agencies were surveyed by county unit. The resulting individual forms were then entered into a computer program.

The NIIMS resource computer program requires an IBM PC or compatible unit with 256 K memory. The software used is RBASE 4000 or 5000, published by Microrim, Inc., and the NIIMS program developed by the Florida Division of Forestry. The data-base size is limited only by the number of bytes per disk. The Florida data is currently stored on two double-density, two-sided floppy disks with approximately 364 K on each.

The two disks contain 1,268 address records, 1,813 radio records and 3,197 equipment records. This does not mean that there are 3,197 pieces of equipment recorded on those two disks; rather, it means that there are 3,197 lines or records available. The actual numbers of equipment recorded are 3,055 of type 1, 2,529 of type 2, 1,620 of type 3, and 1,099 of type 4, for a grand total of 8,303 pieces of equipment on record.

The data-base is divided into three relations—addresses and related data, radios and related data, and equipment types and amounts. For those using RBASE 5000, it may be desirable to rewrite the reports so that all three relations can be accessed at the same time.

To use the data, RBASE is loaded into the PC, the appropriate data disk is selected for the area involved, the data base is called up, and the program is run following the menu and instructions presented on the computer monitor. Editing of the data follows much the same process.

Through the menu, the program will:

1. Display contact data (address, telephone number, etc.) for agencies by cooperator, county, district, or statewide.
2. Display equipment data.
3. Display radio equipment.
4. Display all equipment and radio data for a selected cooperator, county, or district.
5. Search for specific kinds of equipment by county, district, or statewide.
6. Search for specific radio frequencies by county, district, or statewide.

Through the use of RBASE Extended Report Writer software, the data may be manipulated in various ways to produce mailing lists and other products.

For further information on the Florida NIIMS resource inventory, contact J.P. Greene or Jim Brenner at:

Florida Division of Forestry
Fire Control Bureau
3125 Conner Blvd.
Tallahassee, FL 32301

■

The Plastic Sphere Dispenser Aerial Ignition System

James D. Lunsford

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During the early 1960's, Australian foresters developed an aerial ignition system to ignite spot fires in large blocks of eucalyptus to consume litter and reduce a fire hazard (*1*). The system has been used in the United States since the early 1970's by private industry and some State divisions of forestry but was not approved for use by the Forest Service until 1986.

After safety testing by the Missoula Equipment Development Center (ED&T 4E42 P14, May 1985), the Southern Region (R-8) was asked to develop a user's guide on operating procedures prior to approval of the system by the Forest Service.

The operating guide was completed in February 1986, following a workshop held in Tallahassee, FL, and attended by representatives from each Forest Service Region and the Washington Office. Forest Service regulations require each operator to attend an 8-hour workshop to obtain certification to operate the dispenser.

How the Dispenser Works

The dispenser is portable (about 100 pounds) and can be mounted in a helicopter or fixed-wing-aircraft. The dispenser performs the function of systematically injecting the spheres with ethylene glycol (common antifreeze) and dispensing them from an aircraft at a rate of one each 2.6 seconds to three per second. At aircraft speed of 50 miles per hour, ignitions can be placed from 25 to 200 feet apart, as desired. Spacing can be varied by changing dispenser speed and/or aircraft speed.

The machine, a Premo-Mark III dispenser, is manufactured by Premo Plastics Engineering, Ltd., of Victoria, BC, Canada, and has proven to be a very effective aerial ignition system for both prescribed fire and burnout/backfire operations on wildfires.

About the size of Ping-Pong balls (33 mm), the plastic spheres contain 3 grams of potassium permanganate (KM_nO_4). When the spheres are injected with 1 milliliter of ethylene glycol, an exothermic reaction occurs in about 20 seconds, causing a flame sufficient to ignite fine fuels such as grass and pine needles. The system has also been used to ignite logging slash in clearcut areas and windrows of logging slash.

Use of Dispenser

Successful operations were conducted in February 1986 on the Appalachicola National Forest in Florida and the Kisatchie National Forest in Louisiana for fuels reduction burning. The England Air Force Base uses a portion of the Kisatchie National Forest as a firing range for A-10 aircraft. The Forest maintains the fuels on the area to

Figure 1—*The plastic sphere dispenser, mounted in a helicopter, is an effective ignition source for prescribed burns.*

Figure 2—*Plastic spheres containing potassium permanganate are injected with ethylene glycol, causing a flame sufficient to ignite fine fuels.*

prevent escaped wildfire ignited by Air Force use. This year, the Forest Service was assigned a 2-hour period to conduct a prescribed fire between strafing runs. The 3,500 acres were burned in 1 hour using the plastic sphere dispenser and a Bell 206-B helicopter. As the smoke cleared, the A-10's were flying again. Under these conditions, it is imperative to complete the burning operation on time (the Air Force does use real bullets!). In another operation, 11,285 acres were burned in 9.4 hours of flight time over a 3-day period.

Cost of ignition is about $1 per acre. Plastic spheres are about 13 cents each, and antifreeze is inexpensive. One ignition spot per acre gives satisfactory results in the piney woods of the South. The dispenser holds 1 gallon of antifreeze, which will inject 7,000 spheres. Thus, the dispenser has the capability of burning 7,000 acres without the helicopter returning to the helibase. If the burn boss is on board the helicopter, several areas can be burned during a single flight.

Linear spacing of ignition with the wind causes excessive heat as flank fires merge. A grid pattern with shorter flanks seems to produce less intensity (*2*).

Holding crews are needed on each burn unit but may progress to another unit because of short burn out time.

Efficiency and simplicity of the plastic sphere dispenser make it a desirable alternative ignition source for prescribed fire and wildfire burnout.

Literature Cited

1. Baxter, J.R.; Packham, D.R.; Peet, G.B. Control burning from aircraft. Melbourne, Australia: CSIRO Chemical Research Laboratory; 1966. 26 p.
2. Johansen, R.W. Prescribed burning with spot fires. Georgia For. Res. Pap. 49. Macon, GA: Georgia Forestry Commission; 1984. 7 p.

Fine Tuning the Incident Command System

James R. Abbott

ICS working team chairman, forest supervisor, Lincoln National Forest, Alamogordo, NM

The Incident Command System (ICS) received an effective test on an interagency basis during the 1985 fire season. Although some units had little time to train and prepare, their first use of the system on actual fires went quite smoothly. This learning experience provided a practical means of bridging gaps between fire management systems and promoting an understanding of the differences in terminology and organization. It also provided an opportunity for experienced and knowledgeable people to critique the system and begin to suggest improvements that should be made. In addition, adaptations to local needs were considered.

As all agencies gain experience in using ICS there will be a natural tendency to propose modifications to meet specific local concerns. ICS is intended to be flexible enough to meet local needs; however, uncoordinated, independent changes could affect the system's utility as an interagency tool. It is also probably true that some changes are suggested only because new users do not fully understand how a particular problem is meant to be handled.

Other organizations such as law enforcement agencies and various emergency services are also adopting the system for their use. Although this expansion has many positive aspects it could produce more variations in application that may or may not be applicable to wildland fire. Thus, wildland fire agencies must carefully manage system changes if the intended interagency management benefits are to be realized.

The National Wildfire Coordinating Group (NWCG), through the ICS working team, provides the mechanism to coordinate the maintenance and revision of ICS with appropriate input and assistance from involved and interested agencies. Proposals suggested through team members, if accepted by the NWCG, will be incorporated into the system on a periodic scheduled basis. Without this cooperation, different agency approaches could soon create problems in applying the system in interagency situations.

Controlling system change through the NWCG has a high payoff for the agencies and States involved. Each idea and need can be examined by users in a way that features which enhance the system can in turn be adopted. Fine tuning in this way may require more time but the alternative of each agency modifying the system on a continual basis would seriously detract from the usefulness of the system.

The ICS working team has a set process for considering all suggestions. The process used for considering all suggestions is shown in figure 1.

What can you do if you hav suggestion for improving the Incident Command System?

- Analyze and document the benefits, costs, and consequences of the proposal.
- Review the proposal with agencies that you work with locally to obtain their ideas.
- Submit the proposal through agency channels or to the author or an ICS working team member. ■

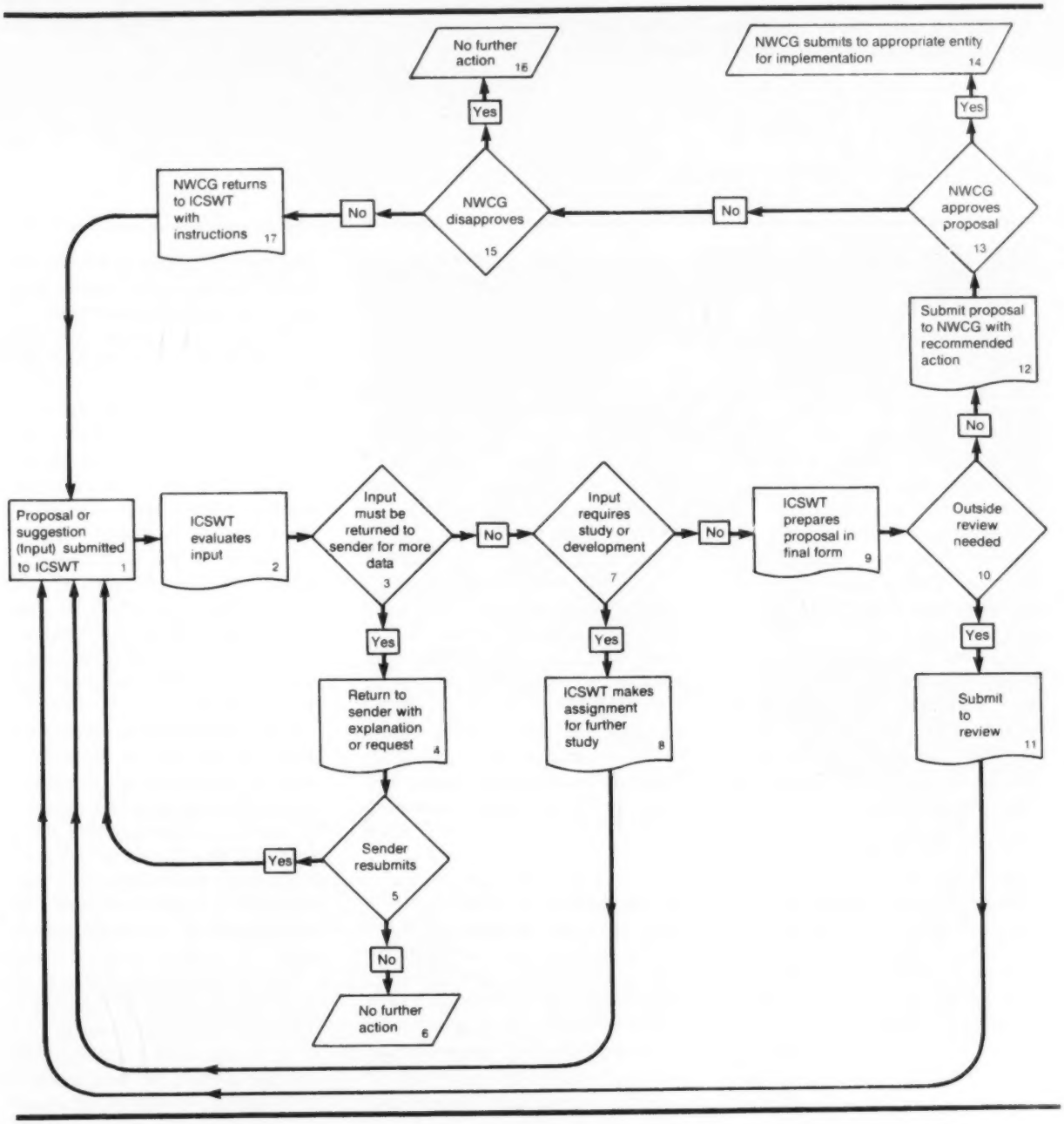

Figure 1—*Process used by the ICS working team (ICSWT) for considering suggestions for modifying the system.*

Fire Division Under ICS

David L. Hanson

ICS working team member, assistant fire chief, Los Angeles County Fire Department, Los Angeles, CA

As it is becoming more widely used across the Nation, the Incident Command System (ICS) has left some of us in the wildland fire protection agencies with questions about how fire incidents are intended to be broken down into manage able geographic areas.

Divisions, as they are described in ICS, are intended to represent a geographical area for the purpose of organizing and directing fire suppression resources on wildland fire incidents. Some of the concerns that have been expressed about the use of ICS divisions include a belief that the division may encompass too large a geographical area and that some additional smaller geographical area designator may be needed. There has also been a reluctance to use ICS divisions on initial attack operations or on small multioperational period fires because of the lack of readily available qualified division supervisors.

Some of these concerns can be addressed by accepting the idea that using the ICS term "division" to refer to geographical areas on your fire incident does not necessarily indicate that the division covers a large area or has a large number of resources or even that a person qualified as a division supervisor is commanding that division. The Initial Attack Incident Commander who separates an incident into two or more divisions, regardless of the size of the incident, has made an important step towards implementing ICS. If the incident escalates in size and complexity the incident commander is in a position to expand the organization accordingly.

Even on a relatively small incident, the Initial Attack Incident Commander, with one crew, can take one side of the fire and call it division A, assigning a second crew to take the other side of the fire, division B. There is no real need to assign someone qualified as a division supervisor to command a division until or unless the personnel and resources required by that division become extensive enough to make such an assignment necessary.

Another concern in our adjustment to the use of divisions in ICS is the loss of the lesser geographical area designator, the sector, that many of us were accustomed to in our previously used incident-management system, the Large Fire Organization (LFO). Perhaps it would be helpful to consider that in the old LFO, even when a sector was used within a division, oftentimes further informal unstructured geographical separations were employed within the sector. For example, the sector boss would have one crew boss cover from point A to point B and another crew boss cover from point B to point C and so on.

It is also perfectly acceptable within ICS to use divisions that incorporate other lesser geographical areas as designated by the division supervisor. For example, the division supervisor on a major incident may decide that he needs help in supervising fire control line-construction in part of the division. He delegates that task to a person qualified as task force leader from among the division's assigned single resource bosses.

It is important to realize that ICS should not be seen as limiting what we do in dividing or organizing our fires. Instead, ICS should be seen as a basic framework for organization that can be applied to initial attack and, if necessary, systematically expanded to handle extended attack or even major incidents.

Sharing experiences, problems, and solutions among all the users of ICS still offers the promise that all of us with a fire protection mission can improve our own operational abilities as well as our ability to work more effectively together. ■

ICS Qualifications

Marvin Newell, Bernie Erickson, and Jim Schneider

Staff assistant and computer systems programmer, respectively, USDA Forest Service; and forester, USDI Bureau of Indian Affairs; Boise Interagency Fire Center, Boise, ID

In 1984 the National Wildfire Coordinating Group's (NWCG) qualification and certification working team, now the Incident Command System (ICS) working team, published the Wildland Fire Qualification Guide *(1)*. This guide includes the NWCG requirements for minimum training, experience, and physical fitness for positions in the ICS. The result of these common standards has been the formation of a nationwide pool of wildland firefighting personnel who are qualified to perform fire suppression jobs for which they have been certified. Some agencies have supplemented the guide with agency requirements for their own use.

After the production of the qualification guide, an obvious next step was to assist managers by developing a data management system to record and track information necessary for qualifications. The ICS working team described the needed criteria, and the Forest Service agreed to develop, test, and recommend such a system to the NWCG. The result was an automated recordkeeping system for wildland fire qualifications that has been accepted by NWCG (fig. 1). The program resides at the Ft. Collins Computer Center (FCCC).

Basically the program is a data management system for personnel involved in wildland firefighting. Qualifications are determined by agency managers rather than by computer analysis. The initial transition to ICS is accomplished by entering the position(s) that the individual has been qualified to perform in, based upon a local management review of his or her training and experience. Target positions for future qualification can be entered as well as subsequent training and experience. Planned training, special skills, or other information can be entered in the remarks section. The program has the capability to create short history files suitable for downloading to microcomputers for use in locally developed applications.

Figure 1—*The automated recordkeeping system for wildland fire qualifications helps ensure that qualified personnel will be available when needed.*

The information is transferred from the data entry form (form 320) to a computer data file format by whatever data entry system is available to the user. Forest Service users can use Forms Entry Systems (FES) on Data General equipment. Other users would have to find a means on their local system that could communicate the resulting data file to FCCC for processing by the program or use data entry facilities available at FCCC.

Agencies or units interested in the system should order the needed materials from the Boise Interagency Fire Center warehouse. There are four items available: User's Guide for the ADP System, catalog #1516; PMS

Form 320 for manually recording and storing data, #1517; red cards with the headings preprinted for typewriter or manual use, #1518; and blank red cards for computer printer use, #1519. The Wildland Fire Qualifications Guide, PMS 310-1, which is necessary for determining national level qualifications, is #1414.

This program is one method of managing ICS data currently available to any user. Individual agencies or units may have or develop other methods to better meet their particular needs. Local agency managers may want to contact their supervisor to determine the best method available to them. ■

Literature Cited

1. Whitson, Jim; Hanson, Dave. How NIIMS Keeps Qualification Standards From Becoming a Barrier to Interagency Cooperation. Fire Management Notes. 45(4): 18.

General Services Administration Supports Firefighters

The General Services Administration (GSA) has been a member of the wildlife suppression community since 1956. Through its Federal Supply Service (FSS), GSA contracts for wildfire suppression equipment and supplies needed to help protect the Nation's forest and grassland resources from the ravages of fire. FSS considers its wildfire suppression equipment program second only to national security in order of priority.

An FSS catalog, "Wildfire Suppression Equipment and Supplies," is the basic supply publication for use by the United States Forest Service, Bureau of Land Management, Bureau of Indian Affairs, National Park Service, and other Forest Service certified participants in the Governmentwide program. Because GSA complies with all regulations governing the competitive purchasing of items, customer agencies may, in compliance with their internal agency procedures, order directly from GSA.

Easy acquisition of firefighting equipment and supplies stocked in GSA warehouses is the first step in GSA's assistance to firefighters. In the event there is any problem with a GSA stock item order, the next important form of assistance is the followthrough provided—that's where GSA's Discrepancy Reports Center comes into play.

At the time catalog orders are received, the merchandise should immediately be checked for visible irregularities such as overages, shortages, or damage. Any carrier abnormalities should be stated on the carrier's delivery form with the carrier's representative acknowledging the same. A report of discrepancies should be sent immediately on Standard Form 361 for carrier discrepancies and on Standard Form 364 for shipper discrepancies (GSA warehouse or vendor) to:

Discrepancy Reports Center
1500 E. Bannister Road
Kansas City, MO 64131

Quality complaints are handled by the GSA Quality Complaint Hotline on FTS 557–1368 (703) 577–1368. Regulatory information regarding discrepancy reporting is detailed in FPMR 101-26.8, "Discrepancies or Deficiencies in GSA or DoD Shipments, Material, or Billings."

Additionally, customer service officers in the GSA regional offices across the country are available to assist firefighters in obtaining wildfire suppression equipment and supplies (telephone numbers and addresses are in the "GSA Supply Catalog"). Discrepancy Reports Center specialists are on hand to assist with order discrepancies on FTS 926–7447 or Autovon 465–7447.

The natural environment is precious, and GSA's Federal Supply Service stands ready to help maintain it.

Louise Nyland
General Services Administration
Washington, DC

Wildfire Prevention: New Perspectives on an Old Problem

Linda R. Donoghue

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Because of certain social trends occurring in the United States and also because of some relatively new administrative requirements, our needs for fire prevention information are changing. I will describe our current system of information gathering, pointing out some of the strengths and weaknesses of the system, and then discuss the new demands for fire prevention information growing out of social change and administrative mandates in the United States.

Most of our current fire prevention information, like yours, comes from our individual fire reports. The key elements from a prevention standpoint are: statistical cause, general cause, specific cause, and class of people. Statistical causes, which are used by all protection agencies in the United States, are reported annually in our "Wildfire Statistics." General cause is defined as the general type of land use activity responsible for a fire, and specific cause as the specific activity or ignition source causing the fire. This cause classification system, though amended occasionally, has been used by the Forest Service for 80 years and appears on State and Federal fire reports in varying formats. When combined with location, size class, and acreage burned information, it not only gives us an idea of what our problems are but where and how big they are. Based on this information, our land managers select appropriate fire prevention programs and allocate resources to solve their wildfire problems. By monitoring trends in fire causes, they also use the information to evaluate the impacts of their programs.

Table 1—*Classification of dump fires in the Northeastern United States*

Statistical cause	General cause	Specific cause	Class-of-people
1. Incendiary	Incendiary	Burning dump	Local permanent
2. Incendiary	Incendiary	Grudge	Local permanent
3. Debris burn	Other	Trash burning	Visitor
4. Debris burn	Resident	Burning dump	Local permanent
5. Debris burn	Incendiary	Trash burning	Local permanent
6. Debris burn	Other	Burning dump	Local permanent
7. Miscellaneous	Resident	Burning dump	Local permanent

Although managers find this process workable, it still can be improved. No matter how much statistical wizardry we scientists perform on the data, we can't make it any better. Although we take what is on the forms and transform it into impressive graphs and charts for our user groups, what comes in must go out. Therefore, if the data coming in are inaccurate what goes out is inaccurate. One of the reasons for inaccurate data is the design of the reporting system; the other part is due to our assessment of fire causes at the fire scene.

First, let's look at the reporting system itself. Ours follows a progression of "add on" information. Eighty years ago, we started with eight basic causes. These apparently were inadequate for over the years new categories (general cause, specific cause, and class-of-people) were added to pinpoint both the cause and who started the fire.

Although to our credit we've maintained consistency in our fire-cause reporting system, unfortunately we've also created categories that are repetitious and not mutually exclusive. As a result, we can easily have multiple classification schemes for a given fire cause, making it difficult to determine from fire-report data the actual cause and person responsible for a particular wildfire. For example, a dump fire set by one or more persons is reported in the Northeastern United States using seven different cause and class-of-people combinations (table 1). What seems simple to record turns out to be complex!

Compounding the problem of overlapping or non-mutually exclusive categories is the broad and repetitious nature of our fire-cause reporting system.

Our system also lacks any way for reporters to indicate the certainty

of their fire-cause data. That is, once entered on a fire report form, reliable causes are indistinguishable from unreliable ones. With no "unknown" category available, an unknown cause is typically classified as a smoking, incendiary, or miscellaneous wildfire. Because reporters cannot indicate the reliability of fire causes, the accuracy of fire-cause data is often questionable, leading to erroneous assumptions about the fire prevention problems.

Even if our reporting system were perfect, we would still have the difficulty of assessing the cause of a wildfire at the fire scene. What it boils down to is that we often don't do a good job of fire-cause investigation. And, if we don't do a good job investigating, what goes on the fire reports and into our data files isn't very good either.

So what are we doing about all of this? It wasn't too long ago that the building block system was proposed to replace our traditional system. This new system included the:

- *Form of heat energy that ignited the fire:* for example, flames, sparks, and hot surfaces from a variety of sources.
- *Reporter's certainty of heat of ignition.*
- *Equipment involved in starting the fire:* e.g., cooking equipment, electrical equipment, woodland equipment.
- *Material first ignited:* grass, leaves, paper, hay, etc.
- *Ignition factor:* how the form of heat energy and the material first ignited combined to start a wildfire—for example, incendiarism, misuse of equipment, mechanical failure, or design deficiency.

This system also included the type of person responsible for fires, the person's age and sex, and the primary activity the person was involved in when the fire started. Although the idea was good, it wasn't widely accepted because it was too cumbersome to use (25 pages of categories to choose from!) and broke too much with tradition.

The Forest Service decided to compromise. Our new fire report contains only statistical causes: debris burning, campfires, incendiary, railroads, smoking, equipment use, children, miscellaneous, and lightning. We're back to where we started in 1905! These are reported uniformly across the Nation. The system is obviously simple to use and historically compatible with previous fire report data. If, however, managers want more detailed fire prevention information for their administrative units, they can also use the building block system contained on a supplemental fire report form.

Finally, to improve the quality of the data, fire-cause investigation is being emphasized nationwide. This is, in part, a reaction to the increase in arson in the United States. Nationally, it's the number one cause of wildfires. To get a better handle on the magnitude of this problem, the wildland fire community has decided to improve its investigative skills. With better investigative work comes better wildfire cause data.

What I've just described is our current system of reporting data that is useful to the fire prevention community. And it's a traditional system. We use the information, as we have for decades, to define our fire prevention problems in terms of number of fires, their causes, acreage burned, and so forth. And, if we're asked to demonstrate our achievements, we point to the increase or decrease in human-caused fires over time. But in our day and age, this is no longer adequate.

With tightening budgets, cutbacks in our management programs and personnel, and mandates from Congress to demonstrate the cost effectiveness of our fire management activities, the Forest Service has implemented a national system for analyzing, from an economic standpoint, fire management programs.

The system provides a formal process for evaluating the efficiency and effectiveness of fire programs at the national and regional levels.

When I say "fire programs," I mean total fire management programs which include wildfire-prevention. In the past, we've

tended to separate prevention from the rest of the fire picture. It was always an isolated event outside of the mainstream. Now, we're looking at the complete picture, including prevention, presuppression, and suppression activities. This brings up a number of questions about the economics of fire prevention programs. For instance:

- How much do our fire prevention programs cost us and what do they "buy" us in terms of number of wildfires?
- What is an efficient program level?
- What is an efficient budget level?
- How many fires do these efficient program and budget levels generate and what's the cost plus net value change of these fires?
- How does fire prevention interact with the rest of fire management? If we reduce the number of fires, how does that affect our suppression forces?

These are some of the questions that those of us in fire prevention are now asking and are required to ask. We're no longer looking at just an increase or decrease in the number of fires but, in addition, the costs and effects of these changes.

So, what kinds of additional prevention information do we need?

Initially we need to document:

1. The kinds of educational, engineering, and law enforcement activities we perform.

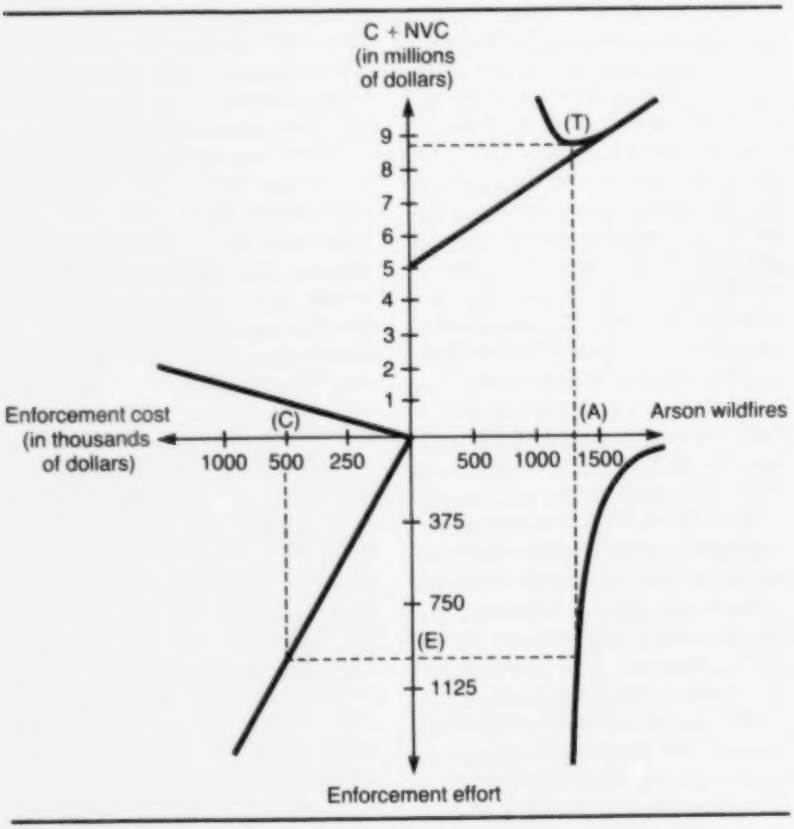

Figure 1—*Nomogram for the State of Arkansas depicting the relationship between the law enforcement program, the number of arson wildfires, and the economic impact of those fires.*

2. How much of each of those activities we perform.

3. How much these activities cost, both fixed and variable costs.

In addition to our suppression costs, we also need to know the net value change in our wildland resources resulting from human-caused wildfires.

All of this information can then be combined into one map or set of nomograms to show, for a particular administrative unit, what our most efficient level of program operation is and what the consequences of that program might be. Figure 1 is an example. We've developed this diagram for the State

of Arkansas. This figure depicts only one aspect of their fire prevention program—law enforcement activities targeted at arson wildfires.

The axis pointing downward reflects the quantity or amount of law enforcement activity (in this case the number of prosecutions, convictions, and settlements) in Arkansas; the axis pointing to the left depicts the cost of these enforcement activities. The axis pointing to the right indicates the number of arson wildfires that can occur in Arkansas, the axis pointing upward shows the suppression costs (C) plus net value changes (NVC) due to these fires.

The lines of this graph represent relationships. The diagonal line in the lower left quadrant, for example, represents the relations between law enforcement activities and the costs of those activities. This line shows that as law enforcement activities increase, the costs of those activities will also increase. We're assuming for the purposes of this exercise that each unit of enforcement, i.e., each prosecution, conviction, or settlement, costs Arkansas $500. The curved line in the lower right quadrant indicates that at low levels of law enforcement effort, Arkansas can expect a high number of arson fires, but as the State increases its enforcement efforts, it can expect a gradual decrease in these fires. Finally, the straight line in the upper right quadrant indicates that as the number of arson fires increases, the C + NVC will increase correspondingly. The curved line in this quadrant reflects Arkansas' total fire management costs, including not only the C + NVC caused by arson wildfires but also the State's prevention (law enforcement) costs.

So, how would a manager in Arkansas use this diagram? Let's assume that the manager is aiming to undertake 1,000 prosecutions, convictions, and settlements against arsonists next year. That level of law enforcement effort (E), could be expected to cost about $500,000 (C). (Follow the dashed line from letter E to letter C.) Given those 1,000 units of enforcement (E), 1,300 arson wildfires (A) could be expected. (Follow the dashed line from letter E to letter A.) The total fire management costs (T), including prevention (law enforcement) costs, would be about $8.7 million—the most efficient level of operation (the lowest point of the curve). (Follow the dashed line from letter A to letter T and over to the C + NVC axis.)

What if the manager's prevention budget were cut in half, from $500,000 to $250,000? What effects would that have? With a $250,000 prevention budget (Enforcement Cost axis), the manager could afford about 500 units of enforcement (i.e., 500 prosecutions, convictions, and settlements). With this reduced level of prevention activity, about 1,400 arson wildfires could be expected. The C + NVC due to these additional fires would be $8.5 million, and the total fire management cost would add up to $8.8 million (C + NVC + enforcement costs).

There's a lot more that we can do with this diagram from an analysis standpoint, but I believe you can get an idea of where we are headed with our analyses of fire prevention programs. Although this is a simplistic model, we're hoping to improve it greatly by collecting cost and prevention activity data for each component of fire prevention so that we can more adequately reflect what's happening in the real world. If we can do that, then we can turn this into an operationally useful system.

Of course, no matter how sophisticated we get, we can't do our job well unless we have good fire prevention information. Some of that valuable information will come from better reporting systems and some from better fire cause investigation. And with improved quality of information, we scientists will be able to give our clients better products to work with. ■

The True Story of the Pulaski Fire Tool

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The nickel-plated pulaski looks as good as new in its glass-fronted Collins Tool Company display case at the Smithsonian Museum of Arts and Industry in Washington, DC. Surrounded by equally shiny cutting tools of all description, the pulaski was first put on display at the Nation's Centennial Exhibit in Philadelphia in 1876.

Conventional wisdom holds that the pulaski fire tool was invented by Edward C. "Big Ed" Pulaski in the second decade of the 20th century. Ed Pulaski, a descendant of American Revolution hero Casimir Pulaski, was a hero of the Great Idaho Fire of 1910, leading his crew to safety when they became imperiled. He was also one of a group of ranger tinkerers who struggled to solve the equipment problems of the budding forestry profession. However, the pulaski tool on display at the Smithsonian must have been made when Big Ed was no more than 6 years old!

In the early days of forestry in this country, fire tools were whatever happened to be available. The earliest methods of firefighting were confined mostly to "knocking down" or "beating out" the flames, and the tools used in the job were simple and primitive. The beating out, when such an approach was possible, was often accomplished with a coat, slicker, wet sack, or even a saddle blanket. A commonly used tool was a pine bough cut on arrival at the fire edge *(4)*.

Soon farming and logging tools, available at general and hardware stores, came into use. These included the shovel, ax, hoe, and rake—all basic hand tools developed over centuries of manual labor. Even after firefighting became an important function of forestry agencies, these tools were accepted as they were, wherever they could be picked up, and little thought was given to size, weight, and balance. There appears to be no record of the use of the Collins Tool Company pulaski for fire control. Most likely, it was sold to farmers for land clearing and may have been forgotten by the late 1800's *(2)*.

With the advent of the USDA Forest Service and State forestry organizations, a generation of "ranger inventors" and tinkerers began to emerge. It became apparent that careful selection and modification was essential for efficient work and labor conservation. In the early days when almost everybody and everything had to travel by horseback transportation was a particular problem. For years foresters worked on the idea of combination tools. Most of the attempts were built in home workshops, and most "went with the wind." Two important survivors, now in general use, are the McLeod tool, a sturdy combination of rake and hoe, and the combination of ax and mattock. The McLeod was probably the first fire tool to be developed. It was designed in 1905 by Ranger Malcolm McLeod of the Sierra National Forest.

Who first invented the ax-hoe combination and used it for firefighting is a matter of minor dispute. Earle P. Dudly claims to have had a pulaski-like tool made by having a lightweight mining pick modified by a local blacksmith. He says he used the tool for firefighting in the USDA Forest Service's Northern Rocky Mountain Region in 1907. Dudly was well acquainted with Ed Pulaski, and the two had discussed fire tools.

Another account of the origin of the pulaski is that William G. Weigle, supervisor of the Coeur d'Alene National Forest, thought of the idea—but not for firefighting *(5)*. Rangers Ed Pulaski and Joe Halm worked under him (all three became heroes of the Great Idaho Fire) at Wallace, ID, then headquarters for the Coeur d'Alene National Forest. At that time, plans were being made for some experimental reforestation, including the planting, pine seedlings. As Supervisor Weigle planned the job, he decided a new tool was needed to help with the planting as well as other forestry work. He decided on a combination of ax, mattock, and shovel. One day in late 1910 or 1911, Weigle sent Rangers Joe Halm and Ed Holcomb to Pulaski's home blacksmith shop to turn out a combination tool that might replace the mattock that was then in common use for tree planting. Halm, with Holcomb helping, cut one blade off a double-bitted ax, then welded a mattock hoe on at right angles to the former blade position. He then drilled a hole in an old shovel and attached it to the ax-mattock piece by means of a wing bolt, placing it so the user could sink the shovel into the earth by ap-

plying foot pressure to the mattock blade.

The rather awkward device was not a success as a planting tool. Probably the whole idea would have been abandoned had not Ranger Pulaski been fascinated with the possibilities of the tool. He kept using it, experimenting with it, and improving it. He soon discovered that the bolted-on shovel was awkward and unsatisfactory. He abandoned the shovel part and also lengthened and reshaped the ax and mattock blades. It is too bad Pulaski did not know about the Collins Tool pulaski—it would have saved him a lot of time. Nevertheless, by 1913 Pulaski had succeeded in making a well-balanced tool with a sharp ax on one side and a mattock or grubbing blade on the other.

Pulaski use now spread throughout the Rocky Mountain region. However, it was used not for tree planting but for fire control. By 1920 the demand was so great that a commercial tool company was asked to handle production.

Although the pulaski went into widespread use in the Rockies in the 1920's, it saw little or no use in other areas. Prior to 1931 the USDA Forest Service had no good internal method for handling equipment development and promotion. Most new equipment ideas were introduced and discussed at the regular Western Forestry and Conservation Association meetings *(3, 7)*.

By the mid 1930's, with the advent of the CCC, fire tools began to proliferate, and the USDA Forest Service sought to standardize tools rather than develop new ones. It was at an equipment standardization conference at Spokane in 1936 that the pulaski tool was proposed for national distribution. The conference instructed the USDA Forest Service's Region 1 to develop and further test a prototype suitable for servicewide use *(6, 8)*.

Figure 1—*Firefighter using pulaski on Plume Creek fire in the Kaniksu National Forest in Idaho.*

Since "Big Ed's" day the pulaski, as well as other fire tools, has undergone continual improvement. Pulaski development is an ongoing effort at the USDA Forest Service's Missoula Equipment Development Center. Careful engineering study, design, and testing have resulted in standards of shape, weight, balance, and quality (fig. 1).

Although Ed Pulaski may not have invented the first fire tool put into general use or even first thought of the tool that bears his name, he did develop, improve, and popularize the pulaski. The General Services Administration now puts out bids for more than 35,000 new pulaskis each

year—a long way from the prototype so laboriously made in Ranger Pulaski's home blacksmith shop *(1)*. ■

Literature Cited

1. Daffern, Jerry. Fire suppression equipment from GSA. Fire Management. 36(2):3–4; 1975.
2. Gisborn, H.T. Forest fire—a mother of invention. American Forests and Forest Life. 32(389):265–268; 1926.
3. Goodwin, David P. The evolution of firefighting equipment. American Forests. 45(4):205–207; 1939.
4. Graves, Henry S. Protecting the forest from fire. Forest Service Bulletin. 82; 1910. 48 p.
5. Hult, Ruby E. How the pulaski became a popular tool. The Regional Forest Ranger—Part Four. Article on file: U.S. Department of Agriculture, Forest Service, Washington Office, History Section.
6. Lowden, Merle S. Equipment development and fire research. Fire Control Notes. 19(4):127–129; 1958.
7. Osborne, W.B., Jr. Fire protection equipment accomplishments and needs. Journal of Forestry. 29(8): 1195–1201; 1931.
8. Pyne, Stephen J. Fire in America. Princeton, NJ: Princeton University Press; 1982. 654 p.

Evaluating Arson-Caused Forest Fires in Wisconsin, 1982–85

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Forest fire arson is a problem of some concern for forest fire control people in Wisconsin. In the past 4 years, 567 forest fires were intentionally set. Wisconsin forestry officials consider this number to be entirely too high, especially considering that the figure covers only those lands protected by the Department of Natural Resources (DNR), or roughly one-half of the State land area. Fire responsibility for the remainder of the State lies with either the township or municipal government.

Forest fire arson, for purposes of this article, consists of fires willfully set by anyone to burn vegetation or property not owned or controlled by the fire setter and without the consent of the owner or owner's agent (*1*).

Wisconsin forest rangers reported 567 arson wildfires in the period from 1982 through 1985. These fires were sorted as to degree of certainty of fire cause according to the following criteria (*2*):

1. *Certain*—Form of cause is established by admission, statement of reliable witness, or physical evidence. This category is intended to cover cases where cause is established beyond doubt.
2. *Reasonably certain*—Cause is established by strong circumstantial evidence. This category covers cases where cause is reasonably certain, but witness statements or physical evidence may not be conclusive.

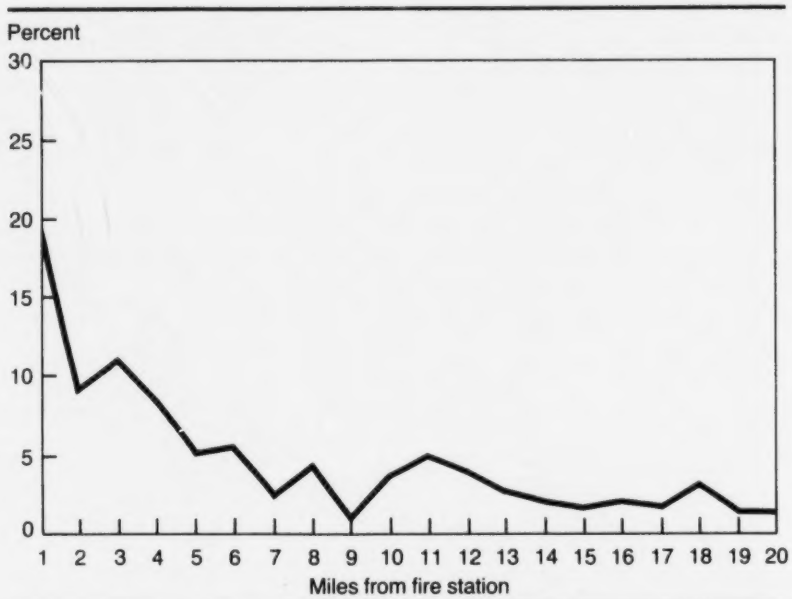

Figure 1—*Distance from fire station of arson-caused forest fires in Wisconsin, 1982– 85.*

3. *Less probable*—Form of ignition is established by weak circumstantial evidence, by process of elimination, or by fire history of the area and experienced judgment of the investigator.
4. *Undetermined*—No definite clues or several probable forms of ignition or fire not investigated.

Only fires that were coded *certain* or *reasonably certain* were selected for the study. Three hundred sixty- one records (64 percent) were coded *certain* or *reasonably certain* by the investigating officers. The persons responsible for 54 arson fires were also identified, and some demographic data were gleaned from their records.

Of the 361 records examined, 201 or 55 percent indicated that the fires were set within 6 miles of the responding fire station. Almost 19 percent of the arsonists set fires within 1 mile of the station (fig. 1). Since most of our ranger stations are located in rural communities this information may indicate that the fire setters live in or near town.

The majority of the arson fires (51.7 percent) were discovered by local residents. This finding is consistent with the percentage of all fires discovered by the local citi-

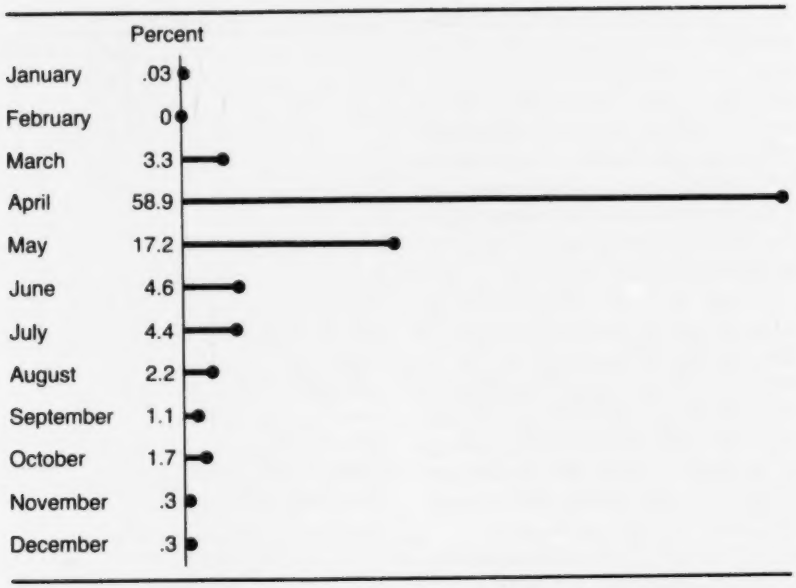

Figure 2—*Arson-caused fires in Wisconsin according to month, 1982–85.*

zenry as opposed to lookout towers, aircraft, or other means.

Almost 60 percent of the incendiary fires occurred in April, and by the end of May, more than 75 percent of the State's incendiary fires had been set (fig. 2). There appear to be two rather significant peaks. One is an 11-day period from April 24 through May 4 when 27 percent of this type arson fires were set. Another peak occurred during a 9-day period from April 9 to April 17, when 19 percent of the fires were set.

April and May are Wisconsin's busiest forest fire months both in numbers of fires and acres lost. Perhaps several factors, such as frequent fire runs by the fire agencies, ease of ignition of forest fuels at this time of year, and the balminess of the weather, combine to stimulate fire setting behavior.

The day of the week that the most fires occurred was somewhat surprising. Sunday ranked highest, with an average of 21 percent occurring on that day; 35 percent occurred on Saturday or Sunday. Forty- eight percent of all the fires occurred on the first 3 days of the week—Monday (14.8), Tuesday (18.4), and Wednesday (14.8). Thursday and Friday ranked the lowest at 9.7 and 7.5 percent, respectively (fig. 3).

Arson fires seem to pick up on Saturdays, peak on Sunday, and then generally decrease to the low of 7.5 percent on Friday. In much of the DNR's jurisdiction, the burning of trash on Sundays is prohibited, following the premise that careless campers, hikers, sightseers, and other recreationists would keep the firefighting forces busy. It appears that, with the demonstrated peak of arson activity on Sundays, the banning of trash burning may be even more justified.

The pattern for time of day for fire starts is interesting. Fire setting activity seems to begin at about 1200 hours, peaks at 1500 hours, decreases to a low point at 1700 hours, and then rises again to a lesser peak at 1900 hours. Fire setting then decreases to a low point at 2200 hours, at which time over

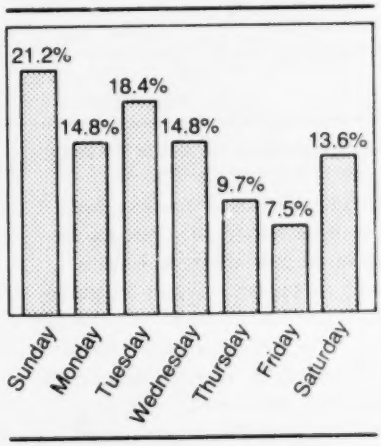

Figure 3—*Arson-caused fires in Wisconsin according to day of the week, 1982–85.*

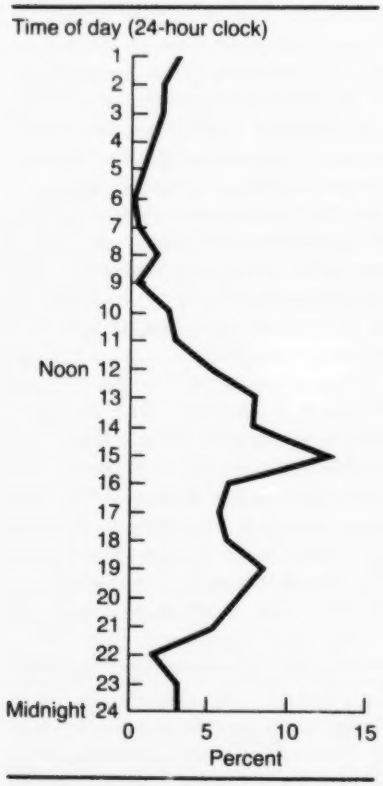

Figure 4—*Arson-caused fires in Wisconsin according to time of day, 1982–85.*

90 percent of the incendiary fires have been set (fig. 4). Perhaps the dip in the late afternoon reflects some chores that have to be accomplished and time out for the evening meal. The increased early evening activity may indicate increased idle time after the evening meal or a desire to re-create the emo-tional "high" attained by the afternoon arson or perhaps both. This daytime fire setting pattern is contrary to the general belief the public has that arson is a crime of the night. Our experience shows that wildland arson occurs in broad daylight during the most dangerous burning time, when our firefighting forces are busiest with accidental fires and when the set fires could potentially do the most destruction.

Another myth was brought down with this study. It had generally been felt that State-owned lands were targets for the arsonists. This proved not to be the case. Private landowners suffered the worst of the attacks—more than 57 percent of the arson fires occurred on private land. Federal lands were singled out next with 15.3 percent, then State lands with 7.4 percent. The remaining fires were on county, municipal, and various highway rights-of-way (fig. 5).

Of the 361 records that were studied, persons responsible for 54 fires were identified. The demographics didn't produce any surprises: 97 percent were male and 63 percent were 25 years of age and under. However, 24 percent were between 38 and 56 years old. There seem to be two main age groups involved in fire setting: 25 and under and the late 30's to early 50's (fig. 6 and 7).

The people that set fires are generally not transients, vacationers, or summer people. Eighty percent were identified as permanent residents, the group most likely to be injured from a forest fire gone awry (fig. 8).

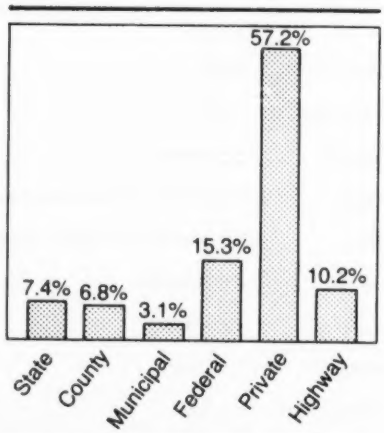

Figure 5—*Ownership of land where arson-caused forest fires originated, 1982–85.*

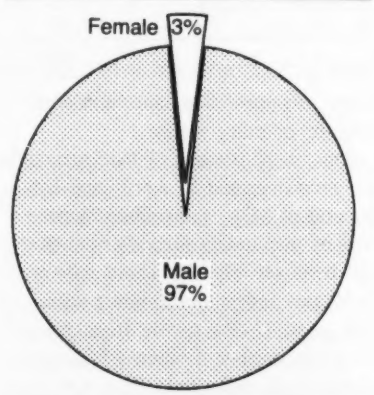

Figure 6—*Sex of known forest fire arsonists in Wisconsin, 1982–85.*

In conclusion, in Wisconsin arson forest fires are more likely to occur during two short periods in April

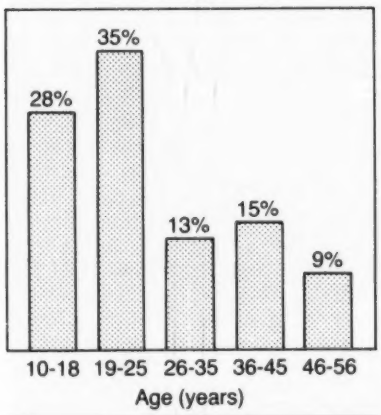

Figure 7—*Age distribution of known forest fire arsonists in Wisconsin, 1982–85.*

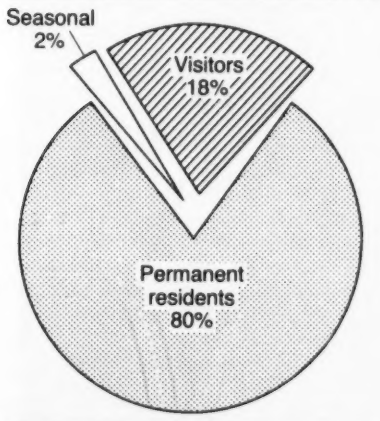

Figure 8—*Residency status of known forest fire arsonists in Wisconsin, 1982–85.*

and May. During these two periods increased vigilance may well be warranted and productive. Fires tend to be set during the day in early afternoon, on private lands within 6 miles of the ranger station. The perpetrator will probably be male, either less than 25 or between 38 and 55 years old. His activity will be most likely on Sundays or Saturdays.

Perhaps the information provided by this study, along with personal knowledge of local conditions, will aid in setting up patrol routes and surveillance procedures that will result in fewer arson fires and the apprehension of arson suspects. ■

Literature Cited

1. U.S. Department of Agriculture, Forest Service. Glossary of terms used in forest fire control. Ag. Handb. 104. Washington, DC: U.S. Department of Agriculture; 1956. 24 p.
2. Wisconsin Department of Natural Resources. Individual forest fire report handbook. No. 4305.1. Madison, WI: Wisconsin Department of Natural Resources; 1981. p. 40–7.

Wildland Firefighters Personal Protection Gear

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Introduction

Wildland fires trapped an estimated 200 firefighters during the 1985 fire season. These entrapments, and the role fire shelters and other personal protective equipment played in saving lives and preventing serious burn injuries, have stimulated great interest. The purpose of this article is to provide field people with additional information on this vital safety equipment.

Fire shelters, special clothing, and other protective equipment exist today because 28 years ago, after an analysis of casualty-causing fires, the Forest Service committed itself to developing effective personal protective gear for wildland firefighters. The Missoula Equipment Development Center (MEDC) has spearheaded this effort over the years and continues to improve the items that make up the firefighter's personal protective system.

Personal Protective System

The basic components of the system include:

- Fire shelter
- Hardhat
- Goggles
- Flame-resistant shirts and jeans
- Leather boots and wool socks

The fire shelter provides protection during fire entrapment and protects vulnerable airways and lungs, which the other components of the system cannot do. We wrote about the fire shelter in the last issue of Fire Management Notes, so here we will focus on the other items of personal protective equipment (PPE).

Properly equipped wildland firefighter in the process of deploying fire shelter.

Together, these items protect firefighters from thermal and other job hazards while they work. Several key requirements guide the Missoula Center's development and test work on PPE. Each item must protect the wearer and not contribute to fatigue or injury by premature failure. In addition, it must be lightweight, functional, durable, comfortable, and economical. With regard to comfort, heat stress is a prime concern. When we speak of economical equipment, we don't necessarily mean the lowest in price. We look at an item's life-cycle cost, not just acquisition cost. A good example is flame-resistant clothing. A garment that costs twice as much as another may still be more economical if it outwears the less expensive garment by a factor of more than two to one.

Hardhat

With the possible exception of the fire shelter, the hardhat is the most important piece of wildland firefighting safety equipment. Hardhats have saved many lives and prevented serious injuries by protecting the wearer against falling trees, limbs, and rolling rocks.

The literature indicates that approximately 15 percent of the body's heat is lost through the head, so hardhats, which are cooler and lighter in weight, are preferred over helmets designed for structural firefighting. Special clips are added to attach goggles and night firefighting headlamps. As wildland firefighters confront more fires in areas where there are structures and associated electrical hazards, class B plastic hardhats, which provide electrical hazard protection, are preferred.

Goggles

A study conducted from 1967 through 1971 showed that eye injuries accounted for about 7 percent of all fire suppression injuries. Dust, smoke, brush and branches, and hot substances cause most eye injuries.

Thus goggles are an important component of the PPE system. Firefighters are dissatisfied with the goggles now available. A recent survey indicated comfortable goggles that won't fog or scratch are one of the firefighter's greatest needs. We hope to begin a project aimed at finding better fog-free goggles for forest workers that will meet firefighting needs.

Development of Flame-Resistant Clothing

Work on flame-resistant clothing began in 1958 concurrently with fire shelter development. The objective was to design garments that would offer firefighters protection (1) against flames, falling embers, and coals; (2) when dashing for safety to avoid entrapment; (3) during entrapment without a fire shelter and added protection within a shelter; and (4) if involved in an aircraft accident.

Extensive use of flame-resistant shirts began in 1962 with the introduction of flame-retardant treated (FRT) cotton shirts. FRT cotton trousers were field evaluated along with shirts. But trousers are subject to greater wear, and FRT cotton had poor durability, so flame-resistant trousers were impractical until Nomex® fabrics became available in the early 1970's.

After using orange FRT cotton shirts for several years, we switched to yellow shirts in the late 1960's. Studies on PPE for urban firefighters showed yellow to be more visible in dark and smokey environments. Also, there were several incidents in which the orange shirts were mistaken for flames and aircraft dropped fire retardant on crews on the line.

Firefighters wore FRT cotton shirts for about 10 years. Then in 1973, after many years of field evaluation, we adopted flame-resistant Nomex® for shirts. Nomex® is woven from a nylon-type fiber designed to withstand high temperatures. Like most fabrics, Nomex® burns if exposed to flame, but unlike the others, it stops burning when removed from the flame. Instead of melting or burning to ash, it forms a char that continues to help protect the skin. In 1974, Nomex® pants became available. We've worked to improve these garments over the years.

Flame-Resistant Shirt

MEDC specialists worked with the producer of Nomex® fiber and several fabric weavers for 3 years to develop a more comfortable flame-resistant shirt fabric. The new fabric has a more open, thicker weave. Weight and fire resistancy remain the same. Forest Service field evaluators said the new shirts are cooler on hot days and warmer on cool nights. The openness of the weave improves evaporative cooling while its thickness traps air next to the skin to keep the wearer warmer at night.

The fabric feels softer, too, evaluators said. The softer fabric should reduce chafing problems some people experienced with the previous Nomex® shirts.

To insure a better fit for more people, the shirts are being made in a new extra-small size.

Key features of the earlier design have been retained. Sleeves are cut full for ventilation plus free movement of the arms. This reduces fabric stress at the elbows and improves durability of the shirt. For added protection against radiant heat and falling embers, the collar can be turned up. Sleeves can be drawn snugly around the wrists with quick-fastening Velcro® closures. Buttons are oversized for easy fastening. Two large pockets with flaps hold maps, note pads, and similar items. The shirt can be worn inside the trousers, or outside of the jacket. Wearing the shirt inside offers the most thermal protection.

Flame-Resistant Jeans

The firefighters pants were redesigned into a basic jean cut. For greater comfort, they have a little fuller cut in the crotch, upper leg, and seat. The new jean design features western scoop front pockets and a return to hook and pile tabs on the back pockets. These pockets remain large for carrying extra personal items and to increase thermal protection with a double layer of fabric.

The zipper fly was retained, but the waistband is now closed with a traditional metal jean rivet button. The button is embossed with the letters FSS for Federal Supply System.

These jeans also come in two new waist sizes: 26 inch and 40 inch. And there is a choice of two inseam sizes, 30 and 34 inches. For those who need 31- or 32-inch inseams, it is easier to let out the 30-inch inseam than to cut and rehem the 34 inch. The 34-inch inseam can be let out to inseams of 35 to 36 inches.

What To Wear with Nomex®

The other clothes worn with Nomex® shirts and jeans affect their protective qualities. Underwear of a polyester cotton blend is acceptable, but we recommend T-shirts and undershorts of 100 percent cotton. All-synthetic underwear should never be worn. Two layers of clothing, that is Nomex® plus underwear, provide better thermal protection. *But don't wear other work clothing under or over your Nomex® garments.* Doing so increases body heat and puts an added load on the heart.

For colder weather and nights, jackets should be all wool, all cotton, or wool blends of at least 85 percent wool.

Coveralls or Jumpsuits

Firefighters in some agencies wear Nomex® or FRT cotton coveralls or jumpsuits, and we are often asked why the Forest Service doesn't use them.

We favor shirts and pants and discourage coveralls and jumpsuits for these reasons: (1) Coveralls are usually worn over other garments. This restricts body cooling, which results in higher heart rates and increased heat stress. (2) Coveralls are made from a single-weight fabric, but ideally different weight fabrics are needed for the upper and lower parts of the body; for example, a heavier, more durable fabric to protect legs from brush and general abrasion, and a lighter-weight fabric with a more open weave to help dissipate heat from arms, chest, and back. One-piece garments of a heavy trouser-weight fabric, like work coveralls, restrict cooling. They also chafe parts of the upper body if worn only over T-shirts. Jumpsuits are made from shirt-weight fabric and do not provide

adequate leg protection. (3) Firefighter's clothing is produced in a limited number of sizes to keep costs down. With such a limited size distribution, one-piece garments seldom fit many people properly because the distance between crotch and shoulders varies so much. In a work situation this causes chafing and discomfort. (4) One-piece garments made from flame-resistant fabrics are expensive. Unlike shirts and jeans, if part of the garment becomes unserviceable, the entire garment must be replaced.

Flame-Resistant Gloves

Specially designed gloves are essential in protecting the firefighter's hands against blisters, scratches, small cuts, and minor burns during routine firefighting. But they also play a major fire protection role in event of an aircraft accident or fireline entrapment.

Reviews of past fire entrapments show that those trapped burned while attempting to flee entrapment sometimes lost fingers if they were not wearing gloves or if their conventional oil-tanned work gloves burned or shrunk from intense heat. Additionally, reports from people entrapped in shelters emphasize the importance of gloves in holding down hot shelter material without getting burned.

After numerous material and design changes, MEDC's latest model forest workers' gloves appear to be meeting firefighting and general forestry requirements very well.

The new gloves are full-grain, chrome-tanned leather; previous models were split-grain leather. Full-grain leather is stronger, so the new gloves wear better and last longer. Full-grain leather requires narrower seam margins to hold stitches, which reduces bulk. Compared with oil tanning, chrome tanning provides excellent protection against heat and shrinkage. These gloves also resist stretching and retain their shape better wet or dry because the leather is water and oil resistant.

A drawstring wrist closure keeps embers and debris from getting into the gloves.

Leather Boots and Wool Socks

Past fire entrapment investigations found that good quality leather boots traditionally worn for wildland firefighting provide adequate foot protection. All-wool or mostly wool socks offer added thermal protection. Wool wicks moisture from the skin. This helps keep feet cooler and dryer, reducing the chance of blisters, a common firefighting injury.

The Forest Service requires the firefighter to wear a lace-type leather boot with at least an 8-inch top. Skid-resistant soles are required, with a lug-type sole preferred. Slips and falls account for many firefighting injuries. One study over a 10-year period indicates that 17 percent of injuries result from slips and falls. So the importance of good skid-resistant soles cannot be overemphasized.

Chain Saw Chaps

One last piece of PPE that we'd like to review is chain saw chaps. Since not all firefighters wear them, we don't include chaps as a component of the basic PPE system. However, due to the extensive use of chain saws in firefighting, we feel a brief review of this item is appropriate.

Chain saw chaps were redesigned in 1982. The redesign focused on increasing sawyer protection and comfort while minimizing costs.

MEDC tested many combinations of materials to find the best protection with the least weight. The new outer shell is 11-ounce Cordura® nylon, replacing the bulky 15-ounce cotton canvas. Cordura® cleans easily, resists tears and abrasions, and keeps the protective pad free of oil better than cotton canvas. The protective pads combine two layers of woven Kevlar® with two layers of Kevlar® felt. Kevlar® is an aramid fiber like Nomex®, but with more flame resistance. Moreover, because of its cut resistance, it can slow and quickly jam the chain before cutters penetrate the leg. At 2 pounds, the new chaps weigh 40 percent less than the old style and offer 50 percent more protection.

Quick-release buckles make the chaps easy to put on and take off. This is a nice feature for firefighting because the chaps can be easily removed to reduce heat stress when

sawing is completed. Leg straps have been relocated to improve fit and minimize snagging, and a tool pouch was added to hold a round file, file guide, flat file, spark plug wrench, and screwdriver. A pamphlet titled "Inspecting and Repairing Your Chain Saw Chaps" is available from the MEDC.

Respiratory Protection

Even though the personal protective system doesn't include any kind of breathing device, we want to discuss briefly respiratory protection.

As we pointed out above, the fire shelter protects the firefighter's airways and lungs during fire entrapment. But what about protecting the working firefighter's respiratory system from smoke, dust, and hot gases?

Periodically, MEDC has been funded to search for effective, practical respiratory protection that does this. Self-contained breathing apparatus used by municipal and industrial firefighters are effective but impractical for wildland firefighting. The Center has tested various types of respirators, and all restrict breathing and don't filter gases well, exposing the wearer to high concentrations of poisonous carbon monoxide and other toxic gases. For this reason, we haven't been able to recommend respirators.

For limited smoke and dust protection, firefighters have worn bandannas for years and are beginning to use disposable dust filters. Bandannas or dust filters should be kept dry. In intense heat, as when working against a hot flame front, there is a possibility that breathing hot, moist air through a wet dust filter or bandanna can damage the respiratory system.

Furthermore, firefighters should be cautioned against covering too much of the face. Cheeks and ears are excellent heat sensors. Covering them can lead a person to work too long in a hot situation. The result can be dehydration, heat stress, and prolonged elevated heart rate leading to premature fatigue, or worse.

Conclusion

Improvement of personal protective equipment is a dynamic process. Materials and production technology change constantly. And new knowledge, particularly in the arena of human physiology, is expanding rapidly. The staff at the Missoula Equipment Development Center keeps up with these changes so as to continue to improve personal protective equipment for the wildland firefighter. We always welcome comments on product improvements. ■

Using Interactive Videodisc Technology in Wildland Fire Behavior Training

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In recent years, fire research has developed a large body of complex information. Proper wildland fire management and use requires a thorough understanding of combustion, fire behavior, fire ecology and history, fire economics, fire effects, and prescribed fire practices. Large areas of valuable resources and human lives are often at stake during prescribed fire and fire suppression activities, making thorough, up-to-date professional training essential. Because safety is such an overriding concern, adequate training is mandatory to reduce risk.

Most fire management organizations require approximately 40 hours of formal training as a basic prerequisite to any entry level suppression position. The curriculum includes fundamentals of fire behavior, fire suppression, fire organization, tool and equipment use, and safety. Fire behavior is central to this curriculum, and a subject taught by all fire management agencies. A complete, multilevel instructional package developed by the National Wildfire Coordinating Group (NWCG) is the training standard in fire behavior for all NWCG agencies.

Our project involves using existing fire behavior curricula in an interactive videodisc/computer training system. This disc will supplement existing training courses in wildland fire behavior and will include materials produced by NWCG on introductory, intermediate, and advanced fire behavior. In addition, elements from existing courses on fuels inventories, debris prediction, and prescribed fire will be included on the program (*9*).

The objective of this project is to demonstrate the application of interactive videodisc instruction to wildland fire management by producing a program on wildland fire behavior. This training package will not replace existing instructional materials, but will act as a supplement to current training materials. The project is funded by NWCG and is being administered by Bureau of Land Management, Division of Training, Boise Interagency Fire Center.

Interactive Training and Instruction

Basic principles of interactive design must be clearly understood in order to realize the benefits which can occur through the use of an interactive training medium. In order to provide useful interaction between the learner and the instructional program, intellectual options should be provided that allow users to actively make decisions and be subjected to their consequences (*1*). For example, an incorrect calculation of a fire's rate of spread in a given simulation may result in inappropriate tactical response to the incident. Learners make choices, and the system responds, sometimes in surprising ways. An interactive videodisc lesson should allow learners to "create" their own training experience, to interview and make frequent decisions about the content of the lesson and the way it is delivered.

The instructional system responds instantly to learner input by providing relevant, previously designed instructional cues, reinforcement, and feedback segments composed of computer text and graphics, still and motion video, with or without audio. The scope, sequence, rate, style, duration, level, and medium of instruction is, to a large degree, determined by a dialog between the learner and the system.

The linear, presequenced format of most traditional instructional materials such as texts, workbooks, films, or slide/tape presentations treats all learners alike and does not allow the learner to actively take part in the choice of sequence or content of a lesson (*5*).

Interactive video is a powerful medium, bringing together the emotional impact of video and film and the interactive capabilities of the computer. Development of interactive videodisc instruction has, to a large degree, mirrored computer-assisted instruction (CAI). Like CAI, interactive videodisc instruction can be used as a tutorial, for drill and practice and in simulations, as well as for information storage.

Designing Interactive Videodisc Instruction

The process of designing, writing, directing, and producing an interactive videodisc/computer lesson in wildland fire behavior is very similar to the basic design and production of an instructional film. However, the major challenge is the integration of various media, designing the dynamic relationship between user and the system, and working with a modular, rather than a linear medium (*4*).

Instructional Matrix. A content matrix for the instructional package in wildland fire behavior was initially developed from a careful analysis of program goals and objectives, existing course materials, learner characteristics, and the various forms of media used within the disc to be selected. This matrix lists the appropriate instructional segments classified by topic and intended learner group in a matrix structure. The matrix thus acts as a "map" to guide the designer in creating the dynamic flowchart that represents the interactive branching training program.

Interactive instruction is designed to be modular and nonlinear, with hundreds of preplanned options available to learners based on prior knowledge of their unique interests, abilities, feedback preferences, primary language ability, and learning styles (fig. 1).

Branching. Videodisc interactivity

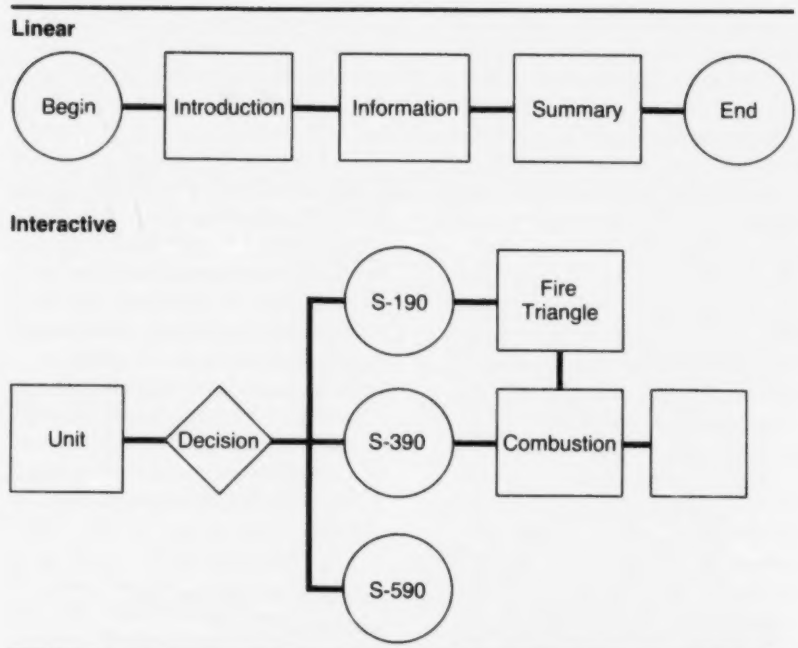

Figure 1—*Linear versus interactive instruction. A linear program has a predetermined format, whereas an interactive program allows the learner to make choices.*

is made possible through a process called branching. A branching program has alternate tracks for the rapid and slow learner, can follow up certain responses in detail, allow learners to see only the materials they need or want to see, test learners on the comprehension of the materials, allow learners to repeat material or to have remedial work when needed, and effectively pose a question without demanding one unique, correct answer. Although branching has been extensively used in computer-assisted instruction, there have been disruptive weaknesses in the quality of video imagery and search time for sequences. The introduction of videodisc technology has been an obvious and practical solution to these problems.

Flowcharting. The branching system developed for the instruction must be graphically represented as a flowchart. The flowchart depicts all instructional events that will be included in the wildland fire behavior training program for the various specified audiences. The flowchart shows each instructional

frame, both still frames and motion sequences, all branching options, menu driven and under program control, all "help" routines, all test items, and dedicated jump forward and review options.

The procedures used in flowcharting interactive instruction are similar to those used in any flowcharting operation. Symbols are very nearly the same, with a few variations to allow for easy identification of the nature of the instructional frame, whether it is a still of freeze frame, or motion sequence. A sample flowchart is shown in figure 2 to demonstrate the complexity involved in the development of an interactive lesson in wildland fire behavior.

Script, Narrative Writing, and Graphics. After the major elements of flowchart construction are completed, scripts and narratives must be written, including all text, computer and quiz screens, and test items. Special terms are used to help integrate the various media, and keep track of hundreds of instructional segments that will be used to individualize instruction for a variety of learners. Scripts and storyboards are then drafted and reviewed for content, style, and feasibility; graphics, animation, and special effects are also planned at this time. Formative evaluation and revision are also appropriate at this stage of design.

Preproduction. The preproduction phase of an interactive videodisc is very similar to that of a film or videotape. However, there are some steps unique to the videodisc medium, including the mapping of the "geographical" layout of the disc, writing of the accompanying computer program, and locating the simple time code numbers for the video frames from the master tape. These steps must be completed before the final production and the mastering of the videodisc (*4, 11*).

Production details will not be discussed, as basic production for a videodisc is almost identical to that of other media such as videotape or film. Once a master videotape of the training materials is edited and contains all instructional sequences, the tape is sent to one of five mastering houses, where the visual images and audio are transferred onto a videodisc.

Hardware and Software Considerations

Intaractive videodisc training is orientad toward the development of learning stations for individual and small group learning. Interactive instruction can take place in any location where an individual or small group can have access to a computer that controls several peripherals, including a videodisc player and monitor (fig. 3 and 4). Input to the computer can be through a touch screen, light pen, or keyboard. The video output from the computer, as well as video/audio from the disc, appears on a single screen or two separate screens. The delivery system chosen for this project uses one screen, allowing both video from the videodisc, and text over the video, which is generated by the computer. "Windows" of video can be opened to illustrate a point described by computer text, or lettering can be written over a video image.

The hardware configuration selected for this project includes an IBM PC computer, Pioneer LD V-1000 videodisc player, and Zenith color monitor. Programming is being done using an authoring system called "Quest."

Expected Benefits

Interactive videodisc technology has proven to be a powerful educational tool, using computer-based learning systems that can display high-quality video imagery, provide rapid access to images, and utilize quality audio. The individualized, self-paced format represented by videodisc instruction focuses on learner needs, rather than a predetermined pace and sequence. A learner is able to choose among a variety of instructional options, and learning is directed according to performance and measurements of understanding. Interactive videodisc allows learners to have remedial

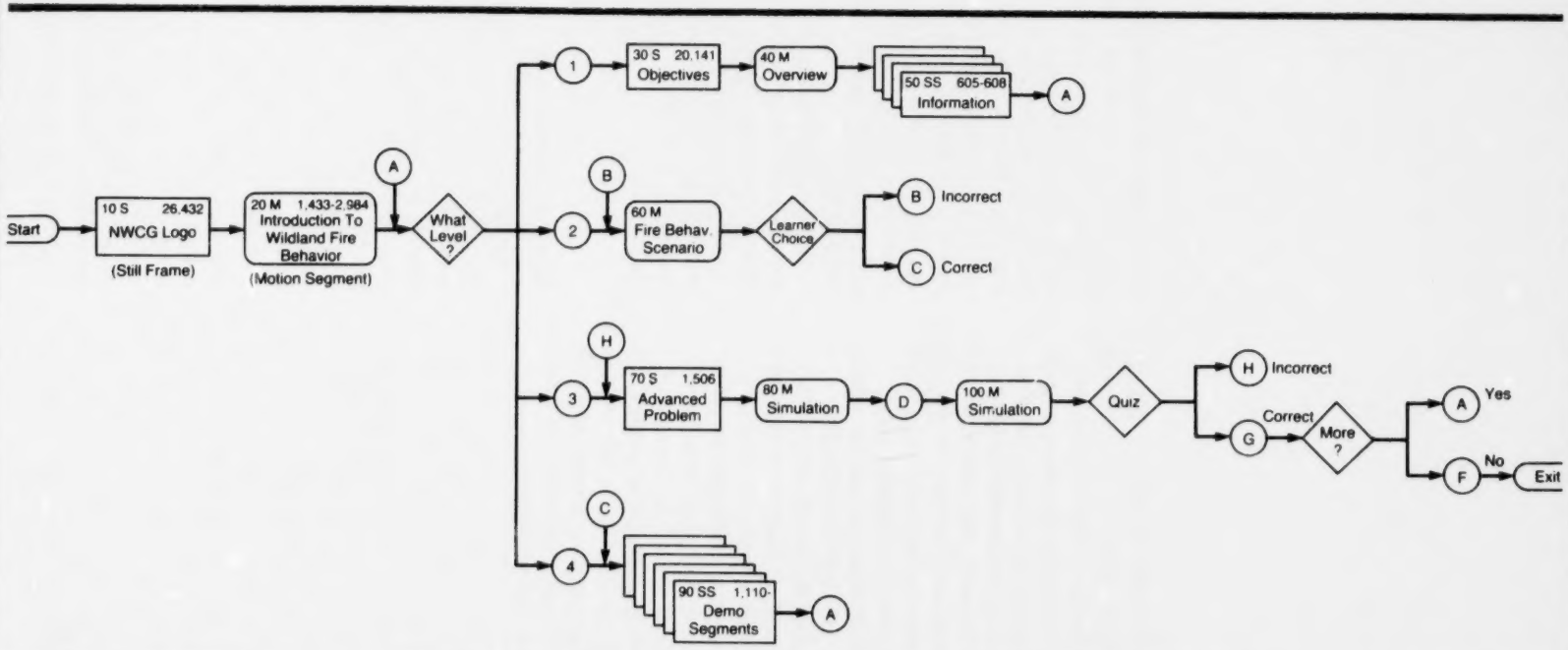

Figure 2—*A sample flowchart showing the complexity of the development of an interactive lesson.*

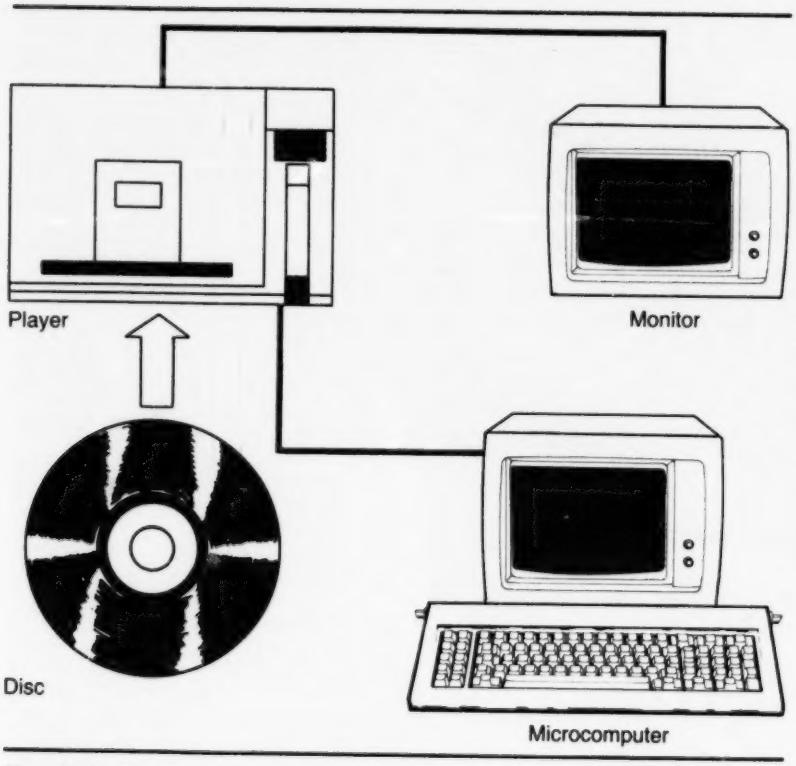

Figure 3—*Hardware components of an interactive videodisc/microcomputer system.*

work if needed or skip ahead if prior mastery is demonstrated.

Other benefits of using interactive systems include: the use of programs by either individuals or small groups, flexible scheduling of training, ease of transport of instruction to remote training sites, and training costs much lower than for traditional training methods.

Recent studies in the comparison of videodisc instruction to traditional methods of instruction have shown numerous advantages from the use of interactive videodisc. Such factors include: savings in actual learning time, higher mastery rate, and favorable response to the medium. Other cost-related benefits are less time spent away from the job, reduced travel/living expenses for training, reduced need for classroom instructors, and use in remote training stations (*6, 7*).

Fire behavior training naturally lends itself to the videodisc medium. Because of the huge storage capacity of a videodisc, beginning, intermediate, and advanced fire behavior training courses can be placed on one disc, allowing the learner to seek remedial help when necessary or go on to advance material when desired. Fire behavior simulation exercises can also be included, allowing learners to apply their knowledge of fire behavior in lifelike scenarios requiring management decisions. Such simulations are more versatile and "transportable" than previously developed fire simulators, and can be used in small or remote centers or for individual use for review or training. The incorporation of tutorial lessons, as well as drill and practice, test items, and information storage make interactive videodisc an efficient, space-saving medium for instruction and a potentially powerful training tool for fire managers and personnel.

Literature Cited

1. Bosco, J.J. Interactive video: Educational tool or toy? Educational Technology. 24: 13–19; 1984.
2. Clark, J.D. How do interactive videodiscs rate against other media? Instruction Innovations. 29: 1–16; 1984.
3. Currier, R.L. Interactive videodisc learning systems. High Technology. 3: 51–59; 1983.
4. Daynes, R. The videodisc interfacing primer. Byte. 7: 48–59; 1982.
5. DeBloois, M.; Bennion, J.L.; Bork, A.; Brandy, R.C.; Knapp, B.H.; Willis, B.D.; Wood, R.K.; Woolley, R.D. Videodisc/Microcomputer courseware

Figure 4—*Videodisc training systems can be used either by individuals or small groups working together.*

design. Englewood Cliffs, NJ; Educational Technology Publications; 1982. 178 p.

6. Ebner, D.G.; Danaher, B.G.; Mahoney, J.V.; Lippert, H.T.; Balson, P.M. Current issues in interactive videodisc and computer-based instruction. Instruction Innovations. 29: 24–29; 1984.
7. Glenn, A.D.; Kozen, N.A.; Pollak, R.A. Teaching economics: research findings from a microcomputer/videodisc project. Educational Technology. 24: 30–34; 1984.
8. Hon, D. Interactive training in cardiopulmonary resuscitation. Byte. 7: 108–138; 1982.
9. Jenkins, M.J.; DeBloois, M.; Matsumoto-Grah, K.Y. Future firefighting—by book or by screen? Training and Development Journal. 39(7): 36–39; 1986.
10. Kindleberger, C.P. Whither the interactive videodisc? Educational TV. 9: 60–65; 1982.
11. Nugent, R.; Christie, K. Using videodisc technology. Video Systems. 2: 16–21; 1982.
12. St. Lawrence, J. The interactive videodisc: Here at last. Electronic Learning. 4: 49–54; 1984.

Florida State Forester John Bethea accepts the Golden Smokey Award from Regional Forester Jack Alcock. Mr. Bethea received this award in recognition of his total commitment to protecting America's forests from wildfire.

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